
SIGILL·COLL·YALEN:NOV:PORT:NOV:ANGL
ET
LUX
VERITAS

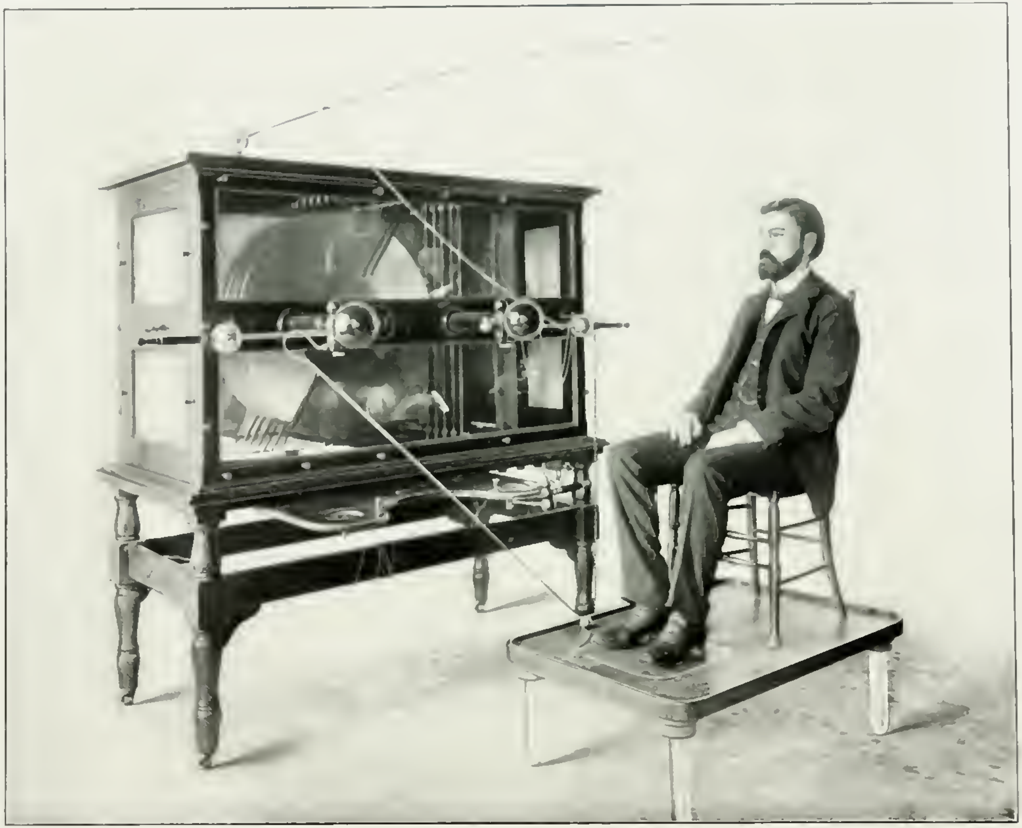

PLATE I

Positive Electrification—Stationary Negative Breeze.

A SYSTEM

OF

ELECTROTHERAPEUTICS

AS TAUGHT BY

THE INTERNATIONAL
CORRESPONDENCE SCHOOLS

SCRANTON, PA.

VOLUME II

ELECTROPHYSIOLOGY

TECHNIQUE AND PHYSIOLOGY OF STATIC CURRENTS

PHYSIOLOGY OF DIRECT CURRENTS

PHYSIOLOGY OF
ALTERNATING CURRENTS AND HYDRO-ELECTRIC METHODS

THE X-RAYS

WITH PRACTICAL QUESTIONS

FIRST EDITION

SCRANTON
THE COLLIERY ENGINEER COMPANY
1900

Printed by
The Colliery Engineer Company,
Scranton, Penna.

5197

SCHOOL OF ELECTROTHERAPEUTICS.

FACULTY.

W. F. BRADY, M. D.,

DEAN OF THE FACULTY.

Professor of Electrotherapeutics and Genito-Urinary Surgery.

WM. J. HERDMAN, M. D., LL. D.,

PROFESSOR OF NEUROLOGICAL ELECTROTHERAPEUTICS.

Professor of Diseases of the Mind and Nervous System, University of Michigan; Fellow American Academy of Medicine; Member American Medical Association; Ex-President American Electrotherapeutic Association.

S. H. MONELL, M. D.,

PROFESSOR OF STATIC ELECTRICITY.

Chief Instructor of New York School of Special Electrotherapeutics; Author of "Treatment of Diseases by Electrical Currents," "Manual of Static Electricity in X-Ray and Therapeutic Uses," "The Cure of Writers' Cramp and the Arm Troubles of Telegraphers and Ball Players," etc., etc.

AUGUSTIN H. GOELET, M. D.,

PROFESSOR OF GYNECOLOGICAL ELECTROTHERAPEUTICS.

Professor of Gynecology in the New York School of Clinical Medicine; Member of the American Medical Association. Ex-President of the American Electrotherapeutic Association; Ex-President of the Society for Medical Progress; Member of the Société Français d' Electrothérapie, etc., etc.

R. B WILLIAMSON, M. E.,

PROFESSOR OF ELECTROPHYSICS.

Late Instructor in Electrical Engineering, Lehigh University.

Contents.

CONTENTS.

PHYSIOLOGY OF ALTERNATING CURRENTS AND HYDRO-ELECTRIC METHODS.

TECHNIQUE

AND

PHYSIOLOGY OF STATIC CURRENTS.

Technique and Physiology of Static Currents.

INTRODUCTION.

1. Rational Tendencies.—The rational tendency of modern electrotherapeutics is to treat the whole patient, and in this way to combat general as well as local maladies. Every application of electricity to the human body, whether general or local, is accompanied by a transformation of electrical energy into some other form of energy. This transformed electrical energy within the human tissues acts either as a physical or as a chemical energy.

2. Function of Static Currents.—The chemical qualities of electricity belong mainly to the galvanic current. The physical qualities of electricity, as a regulator of the various forces of the body and as a distributor of harmony to the equilibrium of the different organic functions, are most conveniently utilized in the different modes of administration of the static currents. The motor, sensory, vasomotor, and secretory nerves are influenced in their physical functions; metabolism is augmented in vigor; by-products are converted into end-products; urea, carbonic acid, and water are increased and eliminated with greater facility; and the entire nervous mechanism of the human organism is brought into harmonious action.

3. Therapeutic Properties of Static Electricity. The physiological and therapeutic properties of static electricity were well known to a few eminent men more than a century ago, but the feeble machines then manufactured were, on account of the uncertainty and difficulty of operating them, not to be

depended on, and consequently fell into disuse. Various forms of apparatus were used prior to 1885, when the improved Holtz induction-machine became the standard. The chief drawback to the popularity and general use of the Holtz machine was formerly in the want of an easy and ready means of communicating to it an initial charge, without which it could do nothing. In 1893 this means was provided in the form of a small Wimshurst charger, which is easily worked and may be relied on to excite electricity in any atmosphere that is not in a high state of humidity.

SELF-TREATMENT.

Before performing operations on the living body, the surgeon acquires confidence in himself and skill in his manipulations by operating on the cadaver. Skill and confidence in static applications are most quickly acquired by self-treatment. Plates II and III illustrate the technique of self-treatment by static currents. The physician can in this manner test the sensory and motor effects of the different kinds of sparks on almost any part of his body. The sensory and motor effects of the long percussive spark and of the short frictional spark, positive or negative, on parts well cushioned, and also on those unprotected by fat and muscles, should be studied and compared. The sensory effects of the breeze and spray, positive or negative, interrupted and continuous, on the bare skin and through fabrics having different resistances, should be carefully studied by the physician on his own body, if he would succeed in applying the breeze or spray with pleasant and beneficial results to his patient.

This method of self-treatment is strongly recommended to the student before he uses static currents on his patients, as it is just as important that he acquire an accurate knowledge of the sensory and motor effects of these currents in order to obtain success as it is for the surgeon to practice operating on the cadaver.

Experiment 1.—Stand on the platform as illustrated in Plate II. With the plates in moderate motion, deliver a few

sparks on the thickest part of the muscles of the leg and then on the forearm 1 inch above the wrist-joint. The positive spark is less penetrating and is milder in its sensory effect than the negative, and should be tried first. Now connect the platform with the positive prime conductor and repeat the same process. The difference between the positive and the negative sparks is due to the higher voltage of positive insulation. Before causing the plates to revolve rapidly, rub the ball electrode briskly over the muscles of the leg, and up and down the spinal column, observing the effects produced.

Experiment 2.—Connect the platform with the positive prime conductor, and sit on the platform chair with the breeze-electrode in your hand. Ground the electrode and the conductor not in use. First test the effect of breeze and spray on the dorsum of the bare hand. Next cover the hand with loosely woven woolen goods and repeat the same process, testing breeze and spray. Different fabrics may be thus tested until the physician has satisfied himself that he is familiar with the effects of different resistances when using breeze or spray with positive electrification. This is the only way by which the physician can learn to develop the tonic, sedative, counter-irritant, rubefacient effects of the negative spray. The bland sedative qualities of the positive spray often elicit expressions of gratitude, yet the counter-irritant rubefacient effects of the negative spray are more closely connected with the pathological lesions of chronic maladies.

Both the positive and the negative breezes are bland and sedative when applied to the bare skin, but the negative breeze through the required resistance can be made to blister the skin with a few minutes' application.

Experiment 3.—Always ground the electrode and the prime conductor not in use. Stand on the platform as illustrated in Plate II, but do not ground either the electrode or the pole not in use. With the plates in rapid motion, apply a few sparks to the quadriceps muscle. Now ground the pole not in use and also the electrode, and deliver a few sparks as before, and note the effects of both applications.

EXPERIMENT 4.—With the machine arranged for potential alternation, as illustrated in Plate VII, start the plates in rapid motion, and separate the ball of the electrode in the movable stand from the terminal of the "shepherd's crook" connected to the positive prime conductor to a distance of about 4 inches, and observe carefully the thickness of the spark stream. Now take the grounding off the fixed electrode, and the spark stream will be diminished one-half. This is a very important experiment, and will demonstrate to the student the advantage of providing metallic grounding for the electrode in order to obtain maximum current-strength, and, therefore, maximum therapeutic results.

THE WIMSHURST STATIC MACHINE.

4. As so much error exists in published descriptions of the Wimshurst machine and in the claims that are made as to its "high efficiency and independence of dampness," as well as its method of action, it is thought necessary to carefully consider this type of apparatus, although its chief use in this country is now simply that of a convenient charger for the more powerful Holtz machine.

5. Construction of the Wimshurst Machine.—The elementary structure of the latest Wimshurst type consists of two circular plates of glass ¼ inch apart, which revolve on an axle in opposite directions. Each plate is coated with shellac, and carries metallic sectors near its periphery. These sectors are placed about 2 inches apart. Each disk has also two tinsel wire brushes supported by brass rods forming an angle of 90 degrees with each other. These brushes afford connection, by means of the rod, between opposite segments on each plate, thereby neutralizing the free charges, in the same manner as in the case of a Thomson replenisher. The external circuit is formed by the combs and their supports and terminals. Each pair of disks added increases the quantity of current. The spark length is nearly equal to the radius of the plates under the best conditions. These machines are made in various sizes, from mere toys up to five or six pairs of plates, 30 to 36 inches

in diameter, or about the size of the standard therapeutic Holtz machines made in the United States. Larger machines are made, but they are exceptions. In France, ebonite is often used for the plates, but is inferior to glass. The Wimshurst machine of small size is a mere toy, and has no practical use. Neither has any static machine of very small size; but, of two 8- or 10-plate 30-inch machines—one Wimshurst and the other the American type of Holtz apparatus—it is found by extensive use of both models that certain claims made for the Wimshurst fail in practice. These claims are:

1. It is very much cheaper in price.
2. It is not affected by dampness.
3. It does not reverse its charge.
4. It requires no case, or if cased it requires no drying material within it.
5. The quantity of electricity is very large and the potential high.
6. It is the best static machine in the world.

Not a single one of these claims can be supported by practical demonstration, but as they are currently quoted in numerous writings and widely believed to be true, the following easily demonstrated facts are submitted:

6. Deficiencies of the Wimshurst Machine.—The Wimshurst machine has an excellent basis of plates, when it is well made; but it is so made as a rule as to be suited only for demonstrating a current. *Almost the only practical field of service for static machines is in medical and X-ray work, and very few Wimshurst machines have complete apparatus for these purposes.* They cost, in proportion to size, nearly as much as the Holtz machine, when they are purchased of dealers. They are about as much affected by dampness as the Holtz machine, and are just as unable to give efficient treatment to a patient in sultry dog-days as if they were not self-exciting. The fact that a current will result from turning the plates is about all that many demonstrators in the past have tested, since few of them have used the machine for clinical work, *which is the practical test of its efficiency.* It reverses its charge far more frequently

and more readily than a high-grade American Holtz machine. It will produce a current without a case, or in a loose-jointed case, but will do better work in a dry room and a tight dry case, well dried with chlorid of calcium. Like every static machine, the volume and potential of the maximum current is in proportion to the number of pairs of plates and to their diameter and speed of revolution. Careful tests of the currents of various Wimshurst machines demonstrate much less efficiency than the Holtz type as employed in the United States. Far from being the best static machine in the world in its larger sizes, it may be said that it is the best and most convenient small machine to serve as a charger for the Holtz, but in the United States the large Holtz machine, by reason of its proved superiority, has practically driven out all Wimshursts of equal size. It is only in the United States that any adequate comparison of the two types has been made; for in England and Europe static machines of any kind are rarely constructed for therapeutic work, and those that use the Wimshurst or its French modifications have nothing to compare its efficiency with, and few, if any, physicians outside the United States have seen or had any competent experience with the machine made here. *Those that have never seen it cannot judge of its merits.* Eminent electrotherapeutists that have done extensive clinical work with static machines and are familiar with European apparatus and the English Wimshurst machine pronounce the best American Holtz machine as without a rival anywhere.

THE HOLTZ INDUCTION-MACHINE.

7. Varieties of Holtz Induction-Machines.—There are obtainable today several sizes of Holtz induction-machines for therapeutic work, but those in most common use are the 6-plate 26- or 28-inch machine, and the 8-plate 30-inch machine. The difference in price between these two machines is not much, but the latter is larger and more powerful than the former. They may be run by hand- or water-power, but a $\frac{1}{6}$-horsepower motor, if a street current is obtainable, will be found the most convenient and serviceable. A rheostat of 150 or 175 ohms

resistance will be required to regulate the motor. Means should be provided for cutting off the current, so that it does not heat in the motor or rheostat when the machine is not in use. The room in which a static machine is placed ought to be large and dry. When first placed in a room the machine should be solidly and evenly fixed. On the proper position of the case depends the steady even motion of the machine, provided that the plates, combs, and internal parts are properly put together. Figs. 2 and 3, Plate XX, illustrate the electrodes employed in therapeutic uses of the static currents, and the insulated electrode handler of Dr. S. H. Monell.

8. How to Keep the Plates Dry.—Ten pounds of calcium chlorid should be divided among three or four fireproof dishes, and placed in an oven until the calcium chlorid is thoroughly baked. The time required for the baking varies, but the important point is to take care that it is thoroughly done. The dishes are then placed within the case of the machine, and the doors instantly closed and firmly secured until it becomes again necessary to reopen the case. During the winter, when the air of the room is dry and heated, the calcium chlorid is not actually needed, yet the inside of the case is a convenient place to keep it. During the spring and fall months the dishes should be taken out of the case at least once a month, rebaked in the oven, and then returned to their former place. In the warm rainy weather of the summer it will be advisable to repeat this process once every week. The condition of the calcium chlorid will determine the necessity of rebaking.

A single 10-pound can of calcium chlorid will in this way serve to keep the interior of the case free from moisture, and the plates and conductor dry for one year, or longer.

9. How to Ground the Poles and Electrodes.—This is readily done when the office is supplied with both gas and water. In the absence of these, two iron pipes can be driven into the ground in convenient places until they reach moisture. Two separate groundings are advantageous—one for the prime conductor not in use and the other for certain electrodes.

Having secured metallic conduction to the earth, either by means of gas- and water-pipes or the two iron pipes driven into the ground, the office terminals of these groundings may be brought to a working distance from the machine by joining to them a piece of stout copper wire. The copper wire may be brought along the wall to within a short distance of the machine and bent to terminate in a hook. A chain that accompanies every static machine is then attached to the copper wire, and the free end of the chain is provided with a hook, by which it is attached to the pole not in use, or to a convenient place on the wall when the machine is not in service. Two grounding connections are advantageous in general practice.

The metallic grounding for the electrode is obtained in the same manner. The chain of the electrode may be directly attached to a chandelier if it is of good conducting material. If the chandelier is not made of good conducting material, a piece of stout copper wire can be secured to the pipe as it leaves the ceiling and brought within reaching-distance of the operator. A gas-bracket on the side of the wall may be used in the same way.

10. Essential Points.—The essential points in the grounding of the prime conductor and various electrodes are:

1. That the connection with the earth is made by metallic pipes instead of merely dropping a chain on the office floor, as is done by many.

2. That the room terminals of the metallic pipes are brought by means of a piece of stout copper wire to a convenient working distance near the prime conductors and the operator. Two groundings are essential in order to obtain all the best results from the static machine. High-potential difference between the two static poles can only be secured by good metallic grounding. *This is one of the most important of the rudimentary principles of using static electricity in medicine. Many have failed to procure good results with fine machines simply through want of knowledge of this fact.*

11. The Platform.—The platform is supported on insulating glass rods 1 foot high, and is usually made of oak with

PLATE II.

Self-Treatment—Static Sparks.

natural-wood surface, which should be smooth. The platform conducts best without a coating of shellac, oil, or varnish, for they are bad conductors and interfere with the passage of electricity to the insulated patient. The corners of the platform are rounded, to lessen the tendency of the electric charge to escape. Moistening the surface of the platform will increase the conductivity, but this is best done by the use of metallic foot-plates connected by a short piece of chain to the platform-rod.

12. The platform is usually placed some distance, about 2 feet, from the prime conductors. If the patient is too near the negative prime conductor, while the platform is connected with the positive pole, and the factors of a strong current and high resistance are present, it may prove disagreeable to the patient. In making all static applications, the operator must habituate himself to keeping out of sparking distance from the patient. Carelessness in moving about the platform will often result in giving the patient an unexpected shock, and in lessening his or her confidence in the skill of the operator.

The electric current is conveyed from the prime conductor to the platform along a metallic rod, curved at one extremity for attaching it to the sliding-pole, and terminating at the other extremity in a round ball, which rests on the platform. This metallic rod should be attached to the sliding-pole with the end of the crook pointing toward the platform.

13. Method of Conducting Current.—There are two methods of conducting the current in a direct manner from the prime conductor to the patient:

1. By placing the metallic conductor in the hands of the patient.
2. By placing a copper plate 15 or 16 inches square beneath the feet of the patient. One corner of this copper plate is perforated, to give attachment to a brass chain about 2 feet long. The metallic conductor may then rest on any part of the platform, and can be connected to the brass plate beneath the patient's feet by means of the chain.

Either of these methods gives direct metallic conduction, which affords the best method when it is desired to use the

entire electric output of the machine. When the current is interrupted by sparks in any part of its circuit, the brass plate under the feet will sometimes prove disagreeable to the patient wearing shoes with thick soles and nails in the heels. To avoid this the rod may be held in the hands.

To determine whether or not the patient on the insulated platform is receiving the full current-strength coming from the machine, instruct him to approach his fingers to the conducting-rod between the platform and the prime conductor. If no sparking occurs on performing this, it shows that the potential of the patient and the prime conductor is the same, and that he is getting the entire current from the machine. If sparking does occur, it demonstrates a difference of potential. The length of the sparking distance affords an accurate measurement of the amount of current-leakage.

14. How to Distinguish Polarity.—*First*, start the machine slowly in motion ; and, with the sliding-poles about an inch apart, observe carefully the first spark that passes. The pole from which it starts is positive, and the one to which it goes is negative.

Second, with the machine in moderate motion, the spark-stream will have a violet color near the negative pole, and there will be a white handle of light coming from the positive pole when the spark-gap is an inch or two in length. With a long gap this is reversed.

Third, with the poles about 6 inches apart and the spark-stream compact, place a grounded electrode on one pole. This will conduct the current to the earth and stop the spark-stream if the pole is positive. If the grounded electrode is placed on the negative pole, the spark-stream will not be interfered with. This is a crucial and very easily performed test for determining polarity, and when correctly done is quick and infallible.

The fox-tail phenomenon is only seen on the positive side of the spark-stream. If the operator from the beginning trains his eye and ear to the motions and noises produced by his machine, he will always be able to determine without these tests what polarity he is using.

15. How to Charge the Holtz Machine.—Without an initial charge the induction-machine is of course useless. This initial charge is now given by a small Wimshurst machine supplied for the purpose. The two poles of the small Wimshurst charger are connected by two metallic rods with the two poles of the induction-machine. Both sets of plates are now set in motion, and the small initial charge communicated by the Wimshurst is multiplied by the plates of the induction-machine into a current of high potential. This process usually requires about a second, but it may require a half-hour if the machines are neglected, damp, and in bad order. If the Wimshurst is of superior make, giving a spark of about 1 inch, the charging is usually rapidly accomplished. During the charging the sliding-poles are placed about an inch apart at first, then short-circuited to disconnect the charger, and then drawn wide apart. A good Holtz machine may run an entire winter with the original charge given at the beginning of the season. Even in summer it will not often discharge if the chlorid is kept dry. It is, however, not any trouble to excite the plates, and the fact that they occasionally discharge is no longer a drawback. Plate IV illustrates method of charging the Holtz induction-machine.

16. How to Discharge the Holtz Machine.—Revolve the plates backward, with the sliding-poles gradually approaching each other until the sparking ceases. Now touch both poles with grounded electrodes. To demonstrate the success of this procedure, set the poles again in motion in the right direction. If the procedure is successful, no sparks will pass, and there will be no evidence of any current.

17. Reversed Polarity.—The Holtz machine rarely reverses its charge, and never during the treatment of a patient. When it occurs it does no harm. If the change of polarity is recognized, the operator can accommodate himself to the change by simply shifting the conducting-rod to the desired pole. A changed polarity may not always be convenient, on account of office arrangement and the formed habits of the operator in using his electrodes.

18. How to Correct Reversed Polarity.—1. The machine must first be thoroughly discharged, and then its positive end lifted slightly from the floor and let drop suddenly. This will jar the plates. This can only be done with one of the smaller machines.

2. The case may be jarred by blows on its side or on the floor.

3. Tap a few times with a hammer on the outer end of the brass cross-rods supporting the upper set of diagonal combs.

To ascertain whether these procedures have been successful or not, it is only necessary to recharge the plates. If these procedures have not been successful, repeat them. It is not necessary to correct a reversal of the usual charge, but the above means can be employed when the operator prefers to do so.

These different manipulations—lifting the positive end of the machine and dropping it with a jar, blows upon the side and floor of the case, taps on the brass cross-rods supporting the upper set of diagonal combs—do no harm to the machine if carefully executed.

PLATFORM METHODS.

19. Static treatment, in the insulating methods of its application, differs widely from the other varieties of electric currents. Well-moistened electrodes and rheostats are not in evidence. Disrobing, which causes so much trouble and loss of time in galvanic and faradic treatment, is entirely dispensed with. The patient steps upon the insulated platform in the same apparel that he or she wears on the street.

20. Character of Static Treatment.—Every static treatment is of necessity *general*. The breeze, spray, or spark may be used to alter pathological conditions in localized portions of the body, but the fundamental principle of static treatment is *general electrification*. The insulated platform is an essential part of static treatment. Without it, there would be no accumulation of electricity, no spark, no breeze, no spray. This may be easily verified by standing on the floor and placing one hand on the prime conductor. The current will

pass through the body in its normal current-strength to the ground. There will be no evidence of accumulation such as is produced on the insulated platform. Sparks cannot be drawn from the body. The hair is not erect. None of the usual static effects are produced.

21. Accumulation.—Accumulation is therefore of vital importance in obtaining therapeutic results, and every care should be taken to make it as complete as possible. The insulated platform is provided with an ordinary chair devoid of all metallic ornamentation. A stool without a back is often very convenient, but a chair with an open back may be made to answer nearly all purposes. In special forms of treatment, particularly in cases of weak and debilitated patients, a reclining-chair or steamer-chair will be found very serviceable. It should be placed on the platform in such a way that the active prime conductor is opposite the head. Attention to this will avoid irritation to the patient from woolen clothing with an opposite breeze.

The patient need rarely be requested to divest himself or herself of metallic ornaments to avoid annoyance during treatment. Hairpins, corsets, buckles, eye-glasses, watches, and jewelry only cause irritation when a breeze or spray is given over them with a strong current, the positive pole to the platform, and with but partial skill. It does not affect a watch.

SIMPLE POSITIVE ELECTRIFICATION.

22. Method of Procedure.—Seat the patient on the platform and connect the positive pole *d* with the platform by means of the usual metallic rod *b*. The patient's feet are placed on the brass plate *c* that is connected with the metallic conducting-rod *b* by means of a chain. The negative pole *d'* is grounded. Set the plates in motion and separate as widely as possible the sliding-poles. During simple electrification, either positive or negative, the sliding-poles should be always separated to their greatest extent. It is only when

Leyden jar currents are used that the poles are approximated. Simple positive electrification is illustrated in Plate V.

23. Character of Simple Positive Electrification. Simple positive electrification, on account of its higher voltage, is much more energetic than simple negative electrification. It subjects the patient to a stronger and more energetic current, and is correspondingly more valuable as a therapeutic agent. *With a powerful Holtz machine in good working order, the choice of poles makes little difference; and, by regulating the dose, nearly equal effects can be produced. With a small machine giving only a small electrical output, it may be always necessary to use the higher-potential polarity.* With a good electric output and proper technique, both polarities may be made to produce almost similar effects. If the negative breeze with positive insulation should prove too irritating, the irritation will be moderated by diminishing the current-*resistance*. The negative breeze is not irritating through cotton material or on bare skin. In the various static applications the *resistance of the clothing* should be carefully studied, and it can be increased or decreased as indications require.

24. The Advantages.—Simple positive electrification has a wide field of usefulness. It is perhaps the great tonic of the future. It is simple and easy to administer, and envelops the patient in an atmosphere of positive electricity. With the machine in rapid motion, large quantities of ozone are also generated. This is inhaled by the patient, and is considered by some to heighten the tonic effects of electricity. The treatment is applicable to any age, to the infant in the mother's arms and to the extreme limits of old age. In cases of simple positive electrification, with no local modifications in method, several persons may be treated at the same time on one large platform. In order to obtain the best therapeutic results, a maximum current is necessary in this form of treatment, and the patient should rest quietly. Conversation is not beneficial during the séance, as it keeps the nervous system more or less excited.

Plate VI illustrates a very useful method of administering simple positive electrification. The patient holds the

connecting-chain in his hand and reclines on a steamer-chair. This puts the patient at complete rest, and enables him, when debilitated from disease, to obtain the maximum benefit from each electrification without fatigue.

SIMPLE NEGATIVE ELECTRIFICATION.

25. Character of the Treatment.—The platform is connected with the negative pole by the conducting-rod. The chain attached to the copper wire leading from the water- or gas-pipe is hooked to the positive pole. The metal plate is placed under the patient's feet or he may hold the conducting-rod in his hand. There is no need to apprehend annoyance during simple negative electrification, on account of the lower voltage of the current. There is seldom any sparking within the case, and no irritating breezes from without. This method of treatment affords a safe means of beginning static treatment in cases of nervous and easily excited patients. Every form of static treatment should be administered with studied care, in order to give to the patient the best therapeutic results with a minimum amount of annoyance. Indeed, it should be the aim of the operator to make every treatment as agreeable and pleasant to his patient as is compatible with thorough energetic treatment.

These two forms of treatment are often called *static insulation* or *static baths.* It is simple electrification *continuous.*

POTENTIAL ALTERNATION.*

26. Essential Features.—By this treatment the patient is submitted to the energetic influence of an interrupted oscillating current. Plate VII illustrates the technique of potential alternation. The platform is prepared the same as for simple positive electrification, and the negative pole *d* is grounded. The essential feature of the method lies in the interruption of

*This is a form of static treatment introduced by S. H. Monell, M. D., author of "Manual of Static Electricity in X-Ray and Therapeutic Uses," and described by him for the first time in 1893.

the current between the prime conductor c' and the patient. The head-electrode a is kept at a distance of about 2 feet and is grounded with the negative pole d. In order to prevent the passage of sparks through the nails in the patient's shoes, place a sufficient number of thick newspapers between the brass-plate electrode and the soles of the shoes.

27. Interrupting the Current.—To interrupt the current, fix the large brass-ball electrode in the movable stand f, and place the ball h of the electrode in contact with the small ball g of the connecting-rod b attached to the sliding-pole d'. The movable brass-ball electrode is now grounded. Different groundings in this form of treatment are advantageous. If the negative pole is grounded to the water-pipe, ground the electrode to the chandelier or gas-bracket. Set the machine in motion, and gradually separate the balls of the electrode and the conducting-rod until the patient experiences a comfortable thrill. This will usually occur at a sparking-gap of 4 or 5 inches, but the author of the method often demonstrates a 10-inch spark. The hair is caused to vibrate vigorously. Both feet should be kept in contact with the metal foot-plate during the entire séance, the usual length of which is 15 minutes. The author of this form of treatment demonstrates by it powerful tonic sedative effects, and strongly recommends its use in cases of exhaustion, mental or physical, no matter how produced.

The effect of the interruption is to energize current action and subject the patient to the influences of an oscillating current. Of the general static methods, it is the most powerful in its tonic action.

Potential alternation, applied as described, is interrupted general electrification. By approaching a grounded electrode to the prime conductor in use, the potential of the patient is reduced to zero. He is again immediately charged by the output from the machine. His potential is therefore made to alternate between zero and the potential of the current employed.

Plates VIII and IX illustrate potential alternation locally applied. In Plate VIII a chain connected to the discharge-rod

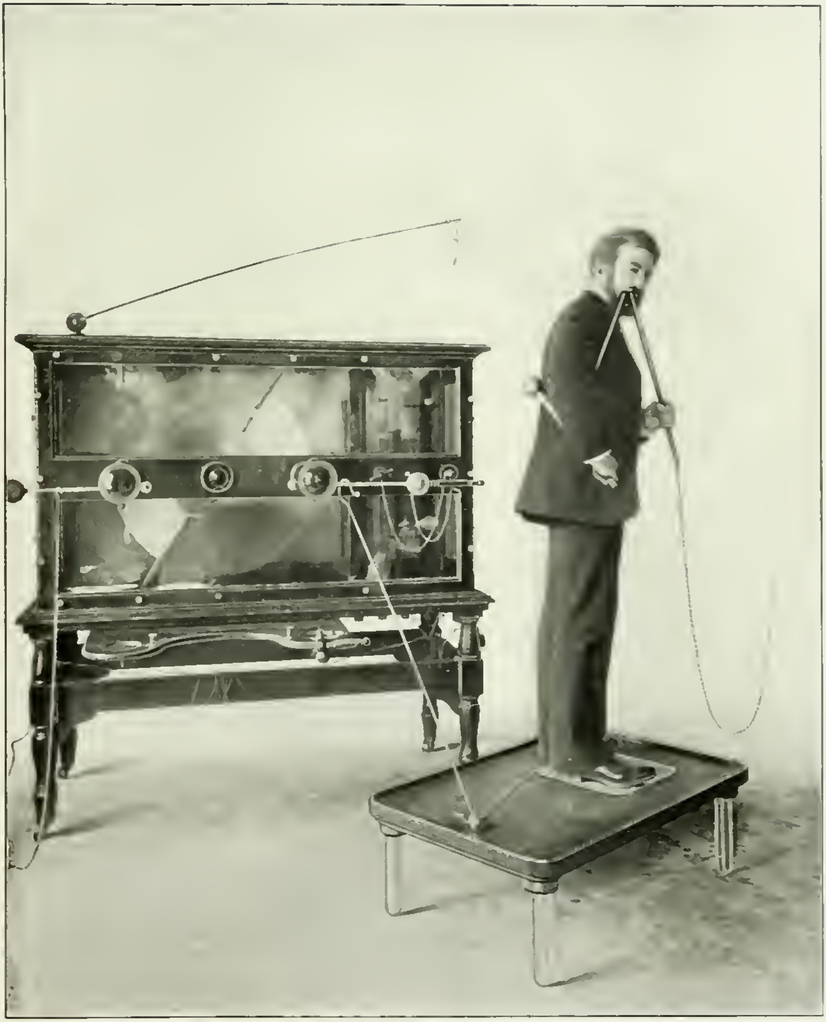

PLATE III.

Self-Treatment—Spinal Friction.

is wound around the muscles of the arm. A grounded electrode interrupts the current on the prime conductor in use. Each spark thus caused produces vigorous, extended, painless contraction of the muscles of the arm. According to S. H. Monell, M. D., there is no method superior to this for exercising the muscles of the arm. The muscles act vigorously beneath the skin, and the skin itself takes on a tanned color, as if exposed to sunlight. The sparks are applied to the prime conductor, and not to the patient, as in the usual spark-treatment.

Plate IX illustrates a technique somewhat different, yet it is potential alternation locally applied. The glass jar is filled three-quarters with water, and becomes the active electrode. On applying sparks to the prime conductor, the muscles of the hand, forearm, or arm will be painlessly exercised, depending on the depth to which the hand is placed in the water. Potential alternation, whether applied as interrupted general electrification, or locally by means of the chain- or bath-electrodes, as illustrated in Plates VIII and IX, constitutes a very important form of static treatment, and one that renders valuable service when tonic sedative effects are required.

LOCAL METHODS.

28. Function.—The three methods of static treatment already described act on the entire system without selecting any special organ or any special symptom on which to localize their therapeutic properties. The methods referred to expend their influence alike on sound and healthy tissues, on organs whose functions are normal, as well as on those whose organic physiology is well-nigh destroyed. The most salient fact of static therapeutics is that each individual submitted to its action receives, during the entire séance, the potential effects of general treatment, and that any special portion of his or her body, whether central or peripheral, may at the same time be modified in its function by local static methods. Nothing like this is possible with the therapeutic methods employed in treating disease with galvanic and faradic currents. The action

of *local* static applications exerts a powerful influence far beyond the area on which it falls. The surface stimulation of sensory nerves, as has been demonstrated by Dr. Hodges, is transported to the central ganglia, where it produces lasting effects. Locomotor ataxia in its first and second stages is thus treated by local static methods, and in the great majority of cases the malady is for a time arrested. This can be explained in no other way than by assuming the transmission of peripheral stimuli to the central ganglia and the establishment there of enduring nutritional effects.

29. Kinds.—The local static methods in the order of their therapeutic properties are the *breeze*, the *spray*, and the *spark*. The breeze and the spray are convective discharges; the spark is a disruptive discharge. The breeze is a current of electrified air thrown from the point or points of an electrode to the body of the patient. The density of this current of electrified air depends on the surface area of the electrode and the number of metallic points implanted on it. Its energy depends on the speed of the revolving plates, the manipulation of the electrode, the state of the air, and the kind and condition of the clothing.

The static breeze may be either positive or negative, and either of these may be made continuous or interrupted, movable or stationary.

THE POSITIVE STATIC BREEZE.

30. Method of Procedure.—The negative pole is connected with the platform, and the positive pole is grounded. For a stationary positive breeze, attach the pointed brass electrode to the movable stand and bring the point to the required distance from the body. On account of its bland and sedative qualities, this is a very serviceable form of treatment in many painful diseases. Another advantage of this method is that the séance may go on for 15 or 20 minutes without the attention of the operator. Plate X illustrates technique of applying stationary breeze to occiput.

31. Nature of Positive Breeze.—In administering the movable breeze, the pointed electrode is held in the hand of

the operator, and is moved back and forth in slow or rapid motion over the region to be treated. The energy of either of these forms of treatment is increased by interrupting the current between the prime conductor employed and the patient. The positive breeze produces a bland and sedative effect. The sensation it causes is cooling and agreeable. It is much employed in irritable and painful conditions, and frequently elicits expressions of gratitude. It is indicated in neuralgia and painful inflammatory conditions, in nervous headache and insomnia. The beginner in statie treatment would do well to familiarize himself with this form of treatment, for it may be confidently asserted that it will well repay his labor. The sedative quality of this form of breeze is no doubt accounted for by the lower negative insulation employed in its use. The main difference between the two poles of the static machine is that of a greater and lesser potential in the same current-action. With the skilled use of the electrodes, and the proper disposition of attractions and resistances, one pole may be made to produce nearly all the effects of the other. Naturally, in simple positive electrification, on account of the higher voltage of the current, the metabolic, nutritive, and other properties of high-potential high-frequency currents will be more pronounced than in simply negative electrification.

THE NEGATIVE STATIC BREEZE.

32. Method of Procedure.—The positive pole is connected with the platform and the negative pole is grounded. The negative breeze may be administered in the same manner as the positive. It may be continuous or interrupted, movable or stationary. On account of the higher voltage of positive insulation, attraction and resistance must be carefully observed. Through linen and cotton fabrics and on the bare skin the negative breeze is cool and sedative, but it may be made highly stimulant and counter-irritant when the skilled operator wishes to produce such effects.

When the hair is very thick, this form of head-breeze with positive insulation may be unbearable. By the patient

continually shifting the position of his head or by keeping the brass-pointed electrode in motion, the negative breeze may be used without causing discomfort when indications demand it. Metal hairpins should be changed for vulcanite. Steel corset-blades will also cause a burning, diagreeable sensation with the negative breeze. In all these cases the essential thing needed to bear in mind is correct regulation of the dose.

33. Nature of Negative Breeze.—The negative breeze, like the positive, is cooling and sedative when applied to the bare skin, or through linen or cotton materials, but it may be rendered strongly irritant in its action by interposing resistance. Applied through loosely woven woolen fabrics it is a very efficient rubefacient and counter-irritant, reddening the skin and causing a sensation of warmth that lasts for some time after the séance is completed. In this way it rapidly relieves neuralgias and the various rheumatic muscular pains.

Cold extremities, sluggish circulation, hepatic, abdominal, and pelvic pains are amenable and frequently yield to this form of treatment. The rubefacient effects may be moderated by slowing the machine, or by leaking off, through the foot on the platform, some of the positive charge. The irritant effects are increased by increasing the motion of the plates, or, better still, by interrupting the current between the prime conductor and the patient.

34. Points to be Noted.—The principal points to be remembered in administering the negative breeze are:

1. It is cooling, sedative, and agreeable when applied to the bare skin or through cotton and linen materials.

2. It is counter-irritant and rubefacient when applied through fabrics (like wool) offering high resistance.

3. Vulcanite hairpins should be substituted for metal ones when a head-breeze is given, and, as far as it is convenient to the patient, all metallic objects should be removed from the person when they interfere locally with the comfort of the breeze.

4. In giving either the positive or the negative breeze, the electrode must be made to adjust the dosage by regulating the distance from the patient according to the effect desired.

5. On account of the prickly burning sensation produced by the negative breeze, when applied through resistances, the electrode should be manipulated over the part treated in such a way as to produce the exact effect desired.

6. It must be remembered that the negative breeze is administered with the higher-potential insulation, and that it can be readily moderated by slowing the machine or by leaking off some of the charge by placing the foot on the platform.

Both forms of breeze, the positive and the negative, are capable of rendering valuable service in daily practice, particularly in cases of minor ailments; but the negative breeze, when used without sufficient care or sufficient knowledge, may prove very disagreeable to the patient. Plate XI illustrates technique by applying stationary breeze to forehead.

THE STATIC SPRAY, POSITIVE AND NEGATIVE.

35. Character of the Static Spray.—The breeze and the spray are convective discharges. The spray is simply a more intense breeze, discharged with the electrode closer to the patient. The breeze discloses no visible change in the atmosphere between the brass-pointed electrode and the surface of the patient's body; yet an electrified current of air is passing from one to the other. In any form of discharge, a circuit is constituted, static electricity becomes kinetic, and a current is flowing. The static spray, positive or negative, throws a convective shower of *visible* electrified particles of air from the brass-pointed electrode to the surface of the body of the individual treated. A more or less intense bluish stream of electrified air is seen passing from one to the other when the room is darkened a little. Neither the breeze nor the spray has the power of contracting muscles, and no muscle-contracting effects can be expected from them. The spray is stronger and more energetic in its action and therapeutic qualities than the breeze. It intensifies all the effects produced by the breeze. It is more sedative and calming than the breeze, when sedative and calming effects are desired; or it may be rendered more

counter-irritant and rubefacient when these latter effects are the indications of treatment. It is used to relieve the same symptoms and treat the same diseases as the breeze. It will well repay a great deal of practice to perfect your skill.

Plates XII and XIII illustrate the technique of administering breeze or spray. Plate XII shows breeze or spray applied to forehead. When using the positive breeze it is well to remember that the positive electrode gives off sparks with great facility and may easily frighten a nervous patient. By carefully observing the point or points of the electrode, this accident may be avoided.

Plate XIII illustrates the technique of the movable negative spray applied to the thorax. A piece of woolen material is placed on the chest to obtain rubefacient and counter-irritant effects. This is a very valuable application in cases of chronic bronchitis and asthma. The energy of the spray may be much increased by interrupting the current in the following manner:

The patient takes the conducting-rod in his hand, and rests one extremity of it on the frame of the case so that it will be about 1 inch from the prime conductor in use. This will interrupt the current between the patient and the prime conductor, and will intensify the effects of either breeze or spray. The counter-irritant effects of the spray are much increased by interrupting the current in the manner described, and by bringing the electrode so close to the body that fine, needle-like sparks mingle with the spray.

Plate XIV illustrates movable negative spray to occiput. When the skull is thickly covered with hair, the negative breeze is irritating, and should be kept moving to be bearable. When the hair is thin or absent, the effect is bland and sedative.

When for any reason a counter-irritant, rubefacient, nutritive effect in the ankle, knee, or any joint is required, the technique shown in Plate XV is a rapid and effective method of treatment. With the proper resistance interposed, the counter-irritant nutritive effects can be regulated with precision. The joint is covered with woolen material, the foot rests on a hassock. The large breeze-electrode is slowly manipulated all around the joint until the desired effect is produced.

THE STATIC SPARK, POSITIVE AND NEGATIVE.

36. The Percussive Spark.—A spark is given by throwing a ball electrode, with a quick movement, to a point so near the body that a disruptive discharge or spark takes place. Static sparks are of two kinds, percussive and frictional. A *percussive spark* is a single discharge. It is a thick, strong, clear-cut spark, varying in dosage from 1 inch to 6 inches in length. A long, thin spark is more burning and penetrating. To give the percussive spark, a large brass-ball electrode is used. (See Plate XVI.) The brass-pointed electrode may be used to administer the breeze, spray, or spark. At a certain distance it throws off a breeze; when placed a little nearer, the breeze will be changed into a spray; and held still nearer, spray and sparks will mingle together. By throwing with a quick movement the brass-pointed electrode to a certain distance from the body, long thin sparks can be given off by an expert, but the ball is usually employed for sparks.

37. The Frictional Spark.—The *frictional spark* is given by rubbing any metallic electrode over the surface of the body. When this is done, a series of electrical discharges takes place. These discharges consist of a number of fine minute sparks, varying in length from $\frac{1}{4}$ to $\frac{1}{8}$ of an inch, according to the thickness of the clothing. The frictional spark may also be given by covering the brass-ball electrode with flannel, and then rubbing it over the surface of the bare skin. The sparks in this case will have a length corresponding to the thickness of the flannel. The positive spark is always milder and less energetic than the negative, because given with negative insulation.

The dosage for sparks may be regulated like that for the breeze or spray. The current may be interrupted or continuous. The machine may be made to go fast or slow as desired, and part of the charge may be leaked off by placing the foot on the platform when it is desired to give a very mild spark.

When using frictional sparks for any purpose, their application may be made much more agreeable by placing the

electrode on the part to be treated before the machine is started into action. By using this method, frictional sparks may be so regulated that their effects vary from an agreeable feeling of heat to the most intense sensory effects desired.

Plate XVII shows ball electrode placed on the spinal region before the plates are set in motion. After each frictional application the machine should be stopped, and the grounded electrode placed for a moment on the platform before renewing the treatment. The ball electrode should be moved rapidly up and down the spinal column for about one-half minute. The time of the application is regulated by closely observing the patient.

38. Precautions to be Taken.—The beginner in static methods will, if not very careful, administer sparks when it is not his desire to do so. Carelessly approaching too near the platform, or want of skill in using the electrodes, will often result in a spark. To give the breeze or spray, premeditation and skill are always required, for without either of these a luckless spark may often occur. The tendency of well-nigh all beginners in static technique is to indulge too freely in the use of static sparks. It is not an unusual thing to see a patient dance about on the insulated platform under the repeated stimuli of long percussive sparks, when a mild, bland, and agreeable application would perform all the therapeutic work. A spark should never be given except in response to a clearly based indication. When spark-treatment is necessary, a mild spark may fulfil all the indications. *Never give a long strong spark when a short mild one will do the work.* A patient should always be prepared for a spark-administration by a fairly clear knowledge of what he is to expect. It is a point of practical importance to reserve spark-treatment until you have gained the confidence of your patient. Before giving the spark, explain to him the sensation he is about to experience. For the first treatment it is advisable to insulate the patient negatively and deliver the spark on some part well cushioned with soft tissues. This will break its force. There are certain parts of the body on which sparks are not given. Generally the

face and head are avoided, but for special indications, mild sparks are even given on these parts, and with very good results. The breasts, both in the male and the female, and particularly the nipples, are very sensitive, and should, in general, be avoided when sparks are being given. The back of the hand, the dorsum of the foot, finger-nails, toe-nails, and bony prominences all over the body should as a rule be avoided. When, however, these various parts are the seat of disease and call for special treatment, the spark may be administered with decided benefit.

39. Function of the Spark.—The spark is the most active and far-reaching in its therapeutic results of all the static methods. A few well-directed, thick, percussive sparks delivered on the soles of the feet of an ataxic patient may bring back sensation that has been lost for months. Each successive treatment lengthens the time during which the returned sensation remains. It stimulates nutrition and the functions of the central nerve-cells. Chronic indurations and exudations are partly resolved and absorbed by it, but it is not equal to galvanism here. It is the remedy, par excellence, for rheumatism, hysteria, and gout. Sciatica—acute, subacute, or chronic—yields more readily to static treatment than any other known remedy. Weak and sluggish muscles are given renewed vigor; muscles and tendons long contracted are loosened and relaxed. It regulates the functions of nerves and muscles and also of the visceral organs.

40. Muscular Effect of the Spark.—The spark produces very strong and widespread muscular contraction. This increases molecular change and aids nutrition, local and general. Sparks rapidly following one another on the same spot cause unnecessary pain, and it is therefore better to administer them with an interval of time and a change of base. A shower of sparks is painful and annoying, and should not be practiced.

Muscles may also be healthfully exercised without the annoyance of sparks applied to the skin. To do this, place an electrode over the motor points of the muscles to be exercised, and by means of a chain connect the electrode to the prime conductor. Now, by applying sparks to the prime conductor,

the muscles are very vigorously contracted. Either hand may be placed in a jar of water containing an electrode connected with the prime conductor. By applying slow sparks to the prime conductor the whole arm is vigorously exercised.

41. Frictional Sparks.—Static technique may be modified in this manner so that any group or groups of muscles may be slowly or rapidly contracted, producing the physiological action of the slowly interrupted faradic current or all the vaso-constrictor effects of the rapidly interrupted fine-coil current. The frictional sparks are used for their counter-irritative and rubefacient effects. They are used in treating anesthesia and other altered conditions of sensation. In general they may be used whenever a counter-irritant is indicated. Their influence extends far beyond the reddened skin. They are used to combat hepatic, abdominal, and ovarian pain. Reflex pain of all kinds is often readily subdued by vigorous friction with the large brass-ball electrode over the regions to which the pains are referred.

The importance of sparks, frictional and percussive, to the perineum is based on the clinical results obtained and on the physiology of the nerves of the perineum. Plate XVIII shows the method of applying percussive sparks to the perineum, and Plate XIX the method of applying frictional sparks to the perineum. Both these methods require practice in the use of static electrodes, and might easily prove disastrous in the hands of a novice.

To the beginner in static methods, the electrode of Dr. Morton is especially recommended. Even with this electrode it is safer to have the plates in slow motion and leak off some of the current through the foot on the platform. With the ball electrode, it requires considerable practice to apply either frictional or percussive sparks to the perineum.

Sparks, frictional and percussive, constitute the best therapeutic application of static currents in the hands of a skilful operator. They will, however, in many cases prove unsatisfactory unless employed as directed by S. H. Monell, M. D. When sciatica, lumbago, or pain in the shoulder-joint do not

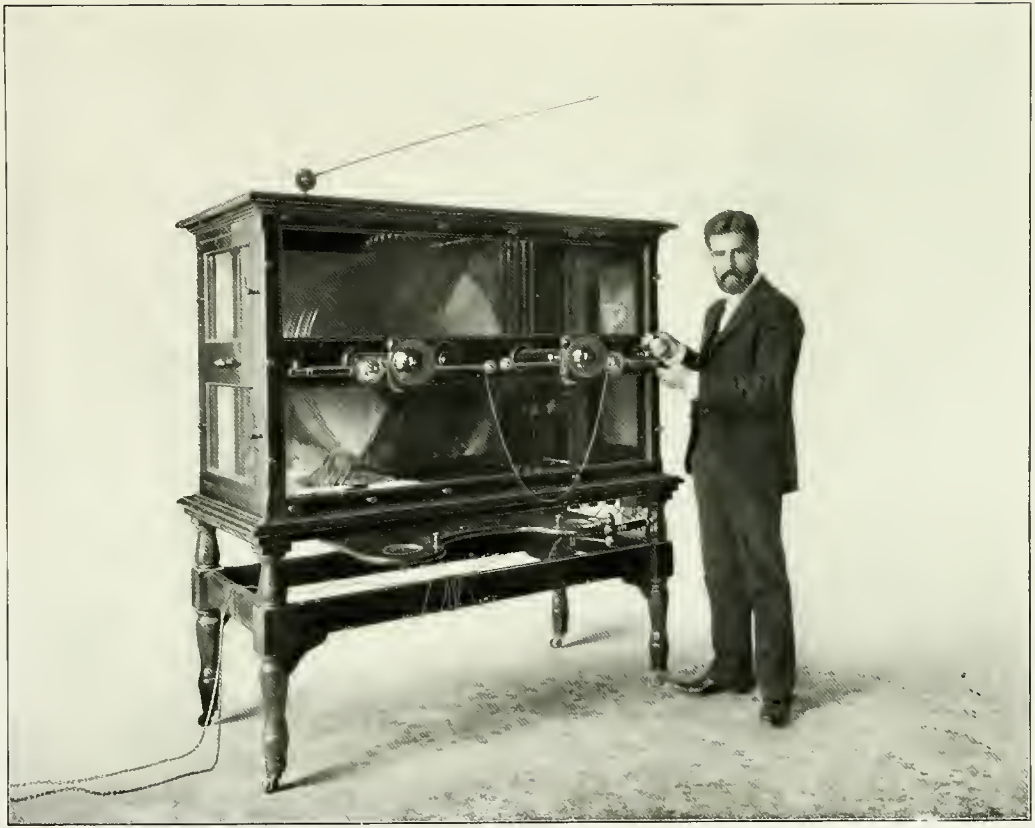

PLATE IV.

Method of Charging Machine.

yield to ordinary treatment, this authority on static therapeutics recommends that frictional or percussive sparks be applied when the muscles are placed in that position which causes most pain. Plates XXVI, XXVII, and XXVIII are given to illustrate postural treatment in the relief of pain. Pain will often yield to sparks applied in this position when it would not if the patient were quietly sitting on the platform-chair.

STATIC CAGE.

42. Principles of Operation.—This is a form of static treatment introduced within recent years. It involves and extends the principle of the static breeze. From a single brass-pointed electrode, a single current of electrified air is projected to the surface of the patient's body. Multiplying the number of points increases the number of currents, but diminishes current-density. A breeze coming from twenty or more points is, of course, much more diffused than when concentrated on one single point, and is correspondingly more bland and sedative in its effects. The static cage (see Fig. 1, Plate XX) would therefore be simply a question of current-density applied in the administration of a static breeze. Instead of presenting one single metallic point to the surface of the body, the static cage simply surrounds the entire body with metallic points, one in close juxtaposition to the other.

43. Method of Using Static Cage.—The static cage may be used in the following two methods: (1) The patient is insulated negatively and treated with a continuous or oscillating breeze. (2) He may be insulated positively and treated with an oscillating breeze.

The patient should remove his shoes and stand in the reservoir foot-electrode if the current is interrupted. The foot-electrode is first filled with warm water, and is connected with the prime conductor. The cage is lowered over the patient so that he stands in its center. There is a distance of about 6 inches between the wires that suspend the cage and the patient's head.

The sliding-poles are short-circuited, and the machine set in motion. Gradually separate the poles until the patient experiences a comfortable thrill. It is always better for the beginner to first try negative electrification and the positive breeze, as the negative breeze might be too irritating or annoying to a nervous patient.

To give a simple breeze the sliding-poles are widely separated at the beginning, instead of being short-circuited.

44. The cage is used for its general tonic and sedative effects. Neuroses and diseases characterized by slowness of nutrition afford the best field for its use. It produces the physiological effects on metabolism ascribed to high-frequency high-potential currents. The chief fact to remember about treatment with the cage is that it is either simple negative or positive electrification, with a continued or interrupted breeze applied to the surface of the entire body. It is a diffuse, extended, breeze application, and much less energetic than the local breeze, and as a tonic is surpassed by potential alternation. Few use the "cage" at present.

MASSAGE-ROLLER APPLICATION.

45. Mode of Operation.—The patient may be insulated negatively or positively, and the electrode and opposite pole are grounded, or the electrode may be connected direct to the active pole. The sliding-poles are brought together and then gradually separated until the required action is produced. This is a very efficient method for causing muscle contraction and at the same time producing lively counter-irritation. Other methods are preferable in most cases.

The muscle-contracting effects, as well as the amount of counter-irritation, are regulated by the distance the sliding-poles are separated from each other, and the speed of the plates, manipulation of electrode, and duration of contact.

The massage-roller electrode may be used with Leyden jar currents. Its satisfactory employment requires skill.

LEYDEN JAR CURRENTS.

46. These currents are used in the same manner and with the same electrodes as the faradic current. Three sets of Leyden jars come with the static machine, viz., large, small, and medium. The question, which one to use, is a matter of dosage. Naturally the larger jars have the greatest capacity, and will give the strongest current. With an 8-plate 30-inch machine run by a $\frac{1}{6}$-horsepower motor, and both in good condition, and a fine-coil apparatus, the physician may find but little use for his Leyden jar currents in therapeutic applications. This of course applies to office practice.

Plate XXI represents the technique of applying Leyden jar currents to the larynx. The smallest-sized Leyden jars are connected with the prime conductors, and an electrode is placed on either side of the larynx. The electrodes are first placed in position; the machine is then set in motion, with the discharge-rods in contact. The discharge-rods are now carefully and slowly separated until the effect required is produced. The electrodes should be thoroughly saturated in a solution of bicarbonate of soda and water. The passage of each spark between the discharge-rods is accompanied by a painless contraction of the muscles in the region covered by the electrodes. The current is alternating. This method of treatment is found very useful in chronic congestion and chronic inflammatory conditions of the larynx.

Plate XXII represents the technique of Leyden jar currents applied to the muscles of the forearm. The small Leyden jars are again used; the palmar surface of the patient's hand makes contact with the sponge placed on the movable stand. This sponge is connected with one Leyden jar; the other Leyden jar is in connection with the electrode held in the hand of the operator. This is a very convenient method of exercising the muscles of the forearm or arm. The interruptions may be made slow or rapid, the current weak or strong, as the physician deems necessary.

Plate XXIII shows the application of Leyden jar currents to the lower extremities by means of the foot-bath electrode.

Ordinary rheophores are used, attached to pieces of block tin or annealed copper, shaped as shown in the foot-bath. This method of applying Leyden jar currents is very useful in producing muscular contraction and in stimulating the nutrition of the lower extremities.

Plate XXIV illustrates another application of Leyden jar currents much used in daily practice. One electrode is applied to the epigastrium, and the other to a point opposite on the spinal column. The dosage is regulated as in all other Leyden jar applications.

Plate XXV shows connections for Leyden jar currents with foot-bath electrode.

47. Comparison of Leyden Jar and Coil-Battery Currents.—For gross nerve and muscle effects, there is little difference between Leyden jar currents and currents administered from a scientifically constructed coil-battery. With slow interruptions in the Leyden jar current the muscles have time to contract and relax, and they undergo the physiological hypertrophy described by Debedat. With rapid interruptions and strong discharge the muscles are tetanized, and if the séance is long, exhaustion will result. The difference in the current coming from small, medium, or large Leyden jars is simply a question of current-strength. The electricity is the same. The larger the Leyden jar, the larger its condensing capacity. Leyden jar currents are not suited for the treatment of inflammatory conditions, and particularly in inflammatory pelvic troubles. The Leyden jar current is less steady and more uncertain in its make and break than the current coming from a well-constructed coil-battery. The physician may easily demonstrate this to his own satisfaction by testing both currents with a telephone receiver. The current from the well-constructed coil-battery will be found smooth and even in its workings; the current from the Leyden jars will be found unsteady, jerky, irregular, and interspersed here and there with secondary discharges. It is for this reason that the coil-current is universally employed as a pain-relieving agent in acute inflammatory diseases, and particularly in inflammatory

affections of the pelvis. The Leyden jar currents are not suitable in these maladies. The Leyden jar current is regulated by the rapidity of the revolutions of the plates and the distance the sliding-poles are separated from each other. With the speed of the plates regulated, and the distance between the sliding-poles properly adjusted, the largest-sized Leyden jars may be made to produce practically the same effects as the smallest-sized jars. It will be remembered that practically the same thing has been said about the physiological properties of fine and coarse coils. Indeed, with the smallest Leyden jars and rapid revolution of the plates, the effects of a current from a long fine-wire coil are very closely reproduced. The medium-sized jars with rapid revolutions of the plates correspond to the current from the coarse-wire coil rapidly interrupted. The largest-sized jars correspond to the coarse-wire coil, and may be used for the same purpose.

48. It will thus be seen that currents from Leyden jars of different sizes are parallel in their effects to the currents from a scientifically constructed coil-battery. The main fact to be remembered is that Leyden jar currents are not suited to acute inflammatory conditions, and that they are completely superseded by coil-currents in the treatment of painful pelvic maladies.

49. Another point to consider is this : the Leyden jars are charged by the static machine. Now, about all that can be accomplished by the Leyden jar currents can be accomplished in a much more pleasing and agreeable manner by the static machine without condensers. If you possess the static machine, you rarely need the Leyden jars for therapeutic purposes. In X-ray work, however, the condensers often become a necessity. The whole range of faradic therapeutics may be covered by Leyden jar currents, rheophores and electrodes being the same. No rheostat, or current-controller, is absolutely required, as the speed of the machine and the distance separating the poles are the direct and indispensable means of regulating the current-strength. To use a rheostat, therefore, makes an additional

adjustment necessary, and adds no actual value to the treatment; but one can be employed if the operator so desires. The one used is simply an enlargement of the galvanic water-rheostat long familiar to physicians.

USEFUL HINTS.*

50. Don't neglect proper care of the machine.

Don't expose it to damp drafts.

Don't operate it in too small a room.

Don't place the platform and patient too near the machine or gas-fixture.

Don't place objects of furniture so near that they will attract the current from your patient.

Don't stand so near the patient yourself that you will do the same.

Don't allow an electrified patient to touch objects or shake hands with a visitor.

Don't pass so near your electrified patient while directing treatment that you will draw an unexpected spark and startle your patient unnecessarily.

Don't incautiously handle a charged Leyden jar.

Don't seat a patient for treatment on a chair that contains ornamental brass-headed nails in its upholstery.

Don't fail to remember corset-steels, wires, hairpins, buckles, metallic trimming, etc., in directing local application to neurasthenia.

Don't forget that the thickness, dryness, and quantity of a patient's hair will affect the intensity of all applications about the head.

Don't forget that the fit, material, texture, and thickness of garments directly influence some forms of static applications, which must be modified accordingly.

Don't forget that static sparks are not always popular, and remember that you have a patient to treat as well as a pathological condition.

---

* Quoted with the author's permission from "Manual of Static Electricity in X-Ray and Therapeutic Uses," by S. H. Monell, M. D.

Don't forget to ground the electrode.

Don't start the induced current into action with the sliding-poles wide apart.

Don't fail to see that the machine is charged and in working order before you call your patient for treatment.

Don't forget to ground the indifferent pole.

PHYSIOLOGY.

51. Static Electricity a Regulator of Functions. The description of platform methods involved a brief description of the physiological action and therapeutic application of static electricity. Static electricity employed in the form of breeze, spray, or spark, or administered with rheophores and electrodes, with or without Leyden jars, is preeminently a regulator of functions. By chemical analysis it has been demonstrated that it increases metabolism and creates a demand for oxygen within the tissues. This increased metabolism, this created demand for an increased amount of oxygen, is brought about by improving the process of oxidation. In conditions in which the temperature is subnormal, static treatment regulates the heat-producing functions and restores temperature to its normal degree. Irregularities in respiration are rapidly corrected and the normal rhythm restored. Exceptions to this are found in icterus and other hepatic diseases associated with melancholia and subnormal temperatures.

52. Action of Static Electricity.—If the pulse for any reason is too slow, static treatment will increase it to the normal; if it is too fast, it will tend to restore it to its normal rate. An individual with all his organs healthy and their functions normal in themselves and working in harmony will be but slightly affected by a simple static charge. The action of static electricity depends, in a great measure, on its therapeutic indications. One would not give stomach-tonics to an individual whose digestive apparatus was functionally normal, nor morphin to a man of perfect health without emotion and without pain. Certainly, if the stomach-tonics or morphin are

given in these conditions, they will not produce the gratifying response that invariably attends them when exhibited according to their well-known indications. The same is true in the case of static electricity. Pain must exist before it can be removed. Irregularities in cardiac action, either intermittent, too rapid, or too slow; too weak or too strong; irregularities in respiratory rhythm, nervous or congestive; too little or too much secretion or excretion; too high or too low temperature: these are all conditions that must exist before they can be controlled. On the typically healthy individual, static electrification has little or no action. For the individual with this or that functional derangement, one or more, static electricity must be conceded to be one of the most powerful therapeutic agents at the physician's disposal. It cannot replace destroyed tissues, but it can often relieve the pain that they produce. The pain of incurable spinal diseases is often kept completely under control by regular static treatment; the course of the disease is modified and the condition of the patient is rendered comfortable. In cases of paralysis of a curable nature it is the best remedy both in symptomatic treatment and in respect to permanent cure when the galvanic current is not required.

53. Calming Influence of Static Electricity.—One of the most valuable and most frequently utilized qualities of static electricity is its power to calm an irritated nervous system and induce a return to normal sleep. Coincident with this comes increased appetite, restored digestion, and renewed strength and vigor. The well-known danger of drug remedies such as morphin, chloral, bromid of potash, paraldehyde, sulfonal, trional, to treat the various forms of insomnia, ought to give an agent like static electricity, at once effective and without danger, a popularity much more extended than it now enjoys. Reflex pains are but too often the cause of nervous irritability and consequent insomnia. Static electricity administered in the form of friction-sparks is among the most effective agents known to therapeutics to relieve and cure these pains. Painful sensations probably travel along the paths of least resistance, and in their way out create the most direct

route for the inward transmission of counter-electrical impressions that serve to annul the pains.

54. Report on "Standard Electrostatic or Influence Machines."—A summary of modern opinion on the action of static currents may be obtained from the following abstract taken from the report of the committee on "Standard Electrostatic or Influence Machines," presented to the convention of the American Electrotherapeutie Association, and published in the "Times and Register," December 29, 1894:

The physiological effects of static electricity are pretty much all that are produced by electricity. It sets free the potential energy of the cells of the human organism. That is, it excites the cell in such a way that its inherent energy is liberated. Its wide range of effects vary with and depend somewhat on the manner in which it is applied. It causes contraction of protoplasm, both animal and vegetable. It excites nerve-fibers, nerve-cells, and nerve-centers. All of them are excited to functional action and caused to produce their separate effects—motor, sensory, special sense, secretory, sympathetic, vasomotor, etc. It has a mechanical action. It disturbs the molecular arrangement of tissues, and causes a new structural arrangement resulting in modifications of nutrition. Its general effects are of great range and of astonishing importance. They may be briefly stated as follows:

It promotes nutrition of every part it excites; produces marked local and general circulatory effects, and stimulates the vasomotor nervous system. It promotes metabolism and tissue metamorphosis; creates a feeling of refreshment to the system; causes the reabsorption of exudative material of a chronic nature, and has a revulsive action on the skin. It is both a cutaneous sedative and a counter-irritant, and makes a powerful peripheral impression of great value in neurasthenia. The subject of reflex pains is of constant interest to a physician. Pains are often referred by patients to points distant from their origin. Possibly a pain travels along the path of least possible resistance, and in its outward path prepares the way for the return of a curative influence along the same path. No matter

how far from the local irritation a reflected pain may manifest itself, spark the sore place and its impression will track the pain to its seat and drive it out.

We cannot cure altered structure, but we can correct functional pains, and often relieve organic pains by setting up powerful ingoing impressions and displacing the pains.

55. The list of diseases in which static electricity can be beneficially employed is a very long one. In cases of malnutrition it is an excellent tonic. Its great fields are functional and nervous diseases.

Neurasthenia, hysteria, neuralgia, nervous headaches, etc. are rapidly controlled by it. In cord diseases it affords relief from various forms of pain, even when lesions are advanced beyond cure. It is invaluable in rheumatism, chronic synovitis, and chorea. It is one of the best general tonics we possess, and as such is very easy and agreeable of application, and can be used in a great variety of cases. In the treatment of paralysis of curable forms, it is one of the most successful agents we have. During a static séance, to obtain these striking results, the patient must be placed in as favorable a condition as possible. Constrained attitudes, cold drafts of air, annoying or disturbing conditions of any kind, must be avoided.

It was long taught, and is a very prevalent mistake today, that static electricity is a mere "surface" charge, and that its therapeutic effects must necessarily be limited to surface action. Let us see what the truth is.

56. Chief Physical Property of Static Electricity. The chief physical quality of static electricity is its enormous voltage. The quality that any electric current possesses of penetrating bodies or overcoming resistance is due to its voltage. It would therefore seem strange that the faradic and galvanic currents, with their comparatively low voltage, penetrate tissue, and that static electricity, with its enormous voltage, was limited to the exterior. The human body is a conductor of electricity; the air is an insulator. Static electricity, in the physical condition of a charge, has sufficient penetrating power to overcome the resistance of four or more inches of intervening

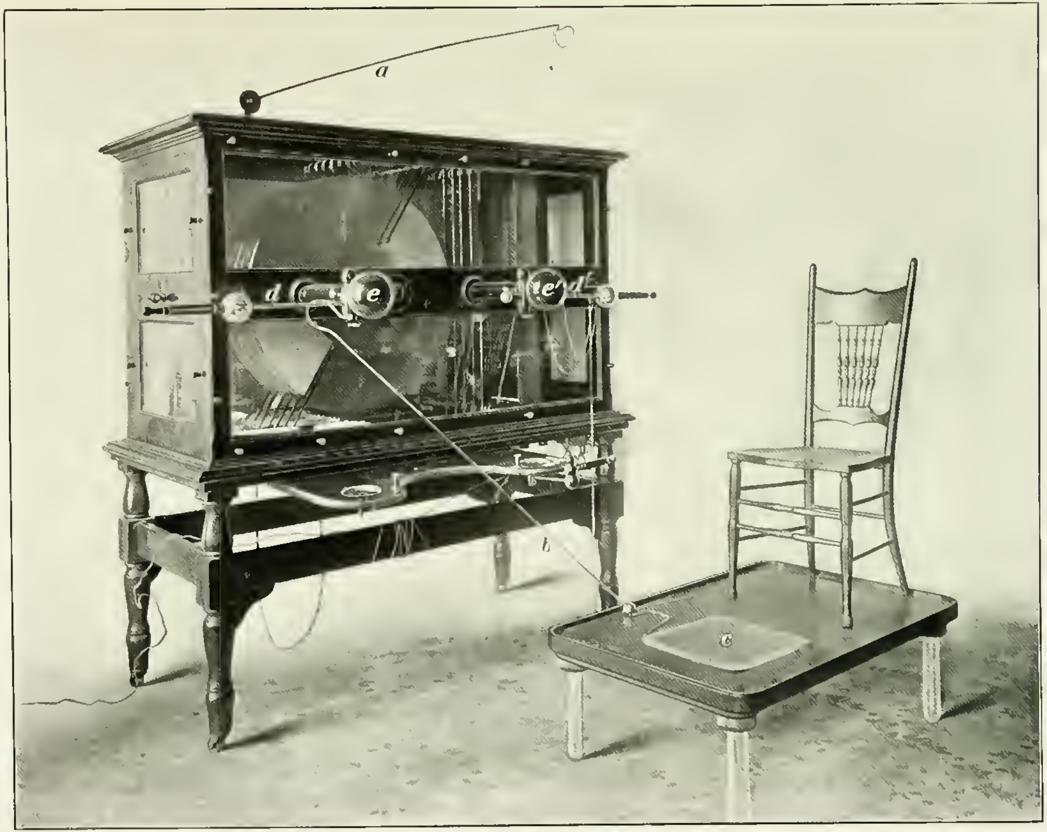

PLATE V.

Simple Positive Electrification.

air, through which it forces its way in the form of a spray or spark. Nothing of this kind can be accomplished by the medical battery, galvanic or faradic. Another striking evidence of the penetrating power of static electricity, due to its enormous voltage, is seen in the phenomenon of an illuminated Crookes tube. No medical faradic battery yet constructed has sufficient voltage to overcome the resistance of the vacuum in a Crookes tube. Surface action would not contract muscles as does the static current, and in many ways the "surface" idea has long been exploded.

57. Its Kinetic Nature.—In these different evidences of penetrating power, static electricity is flowing in a kinetic form. It is not a mere "charge" at rest. When using the interrupted current or Leyden jar current, there is no doubt that the electric current passes through the body from one electrode to the other. When, however, the patient is insulated positively, and the negative prime conductor is grounded, the physical conditions are different, but the current obeys the same electric laws. No one can sit a single moment upon a static platform and have any question about the penetrating properties of static electricity when the facts are demonstrated to his tissues by the point or ball electrodes. Old writers did not test the matter this way, but set up unproved theories, which others kept repeating.

58. Molecular Disturbance Produced.—The static spark produces molecular disturbance in the tissues to which it is applied. New molecular combinations are thus formed, and long-standing exudates and infiltrations are so changed that they can be taken up by the lymphatics and blood-vessels, or eliminated by the different emunctories. The action of the long, clean-cut, percussive spark is essentially mechanical or perturbatory, dissociating the parts of which diseased structures are composed, permitting of new arrangements and healthier combinations. Indurated and infiltrated, thickened and edematous tissues under percussive-spark treatment are often soon absorbed and the affected parts again take on a healthy aspect. The more indications there are for percussive sparks,

the more tolerable will be their application and the more beneficial their results.

59. Nature of the Frictional Spark.—The frictional spark, on account of its efficiency as a therapeutic agent and the facility of its application, requires special notice. It is essentially a rubefacient and counter-irritant, and can be made to vesicate in a few minutes, but this is never done in good practice. As a rule, in medicine, counter-irritation is produced by one of two ways; viz., either by sinapism or by a blister. Other means may be employed, but these two are honored by tradition and are used daily in routine practice; they are, however, both surpassed by static frictions.

60. Counter-Irritation.—No special dogma is needed today to explain the *methodus medendi* of counter-irritation. Claude Bernard and Bichat gave the first glimmerings of the true explanation of the well-known curative powers of counter-irritation in beginning the foundation of physiological therapeutics. Duchenne located, in the anterior cornua of the spinal cord, the real cause of a great deal of myopathic paralysis. Diseased peripheral nerves were next proved clinically and experimentally to produce central spinal lesions. Through work done in the physiological laboratory, reflexes and reflex actions became thoroughly familiar to all physicians. The action of the vasodilator and the vasoconstrictor nerves and their influences on the circulation, local and general, has become common knowledge in medicine, and the physician no longer looks to this or that master for a specious theory to explain the *raison d'être* of counter-irritation. Applied to a large surface of the body for an appropriate length of time, counter-irritation produces a redness of the superficies acted on, and this redness extends for some distance beyond the area irritated; the cardiac action is accelerated, the temperature of the body is elevated, and the irritability of the cerebrospinal system is increased. If this irritation is too violent in its energy, or too long continued, it is capable of working serious mischief. The trophic influence of counter-irritation is made very manifest and convincing in the study of burns or injuries

affecting large areas of skin tissue. It is a well-known clinical fact that the depth of a burn or injury does not affect the trophic condition as much as the extent of surface involved. Thus, the arm may be completely charred to the elbow, and there will follow no pneumonia, no atrophic ulceration of the duodenum. The prognosis of burns depends more on their extent than on their depth; more on the number of nerve-filaments involved than on the intensity of the disease or trauma of any given nerve-fibril. The trophic influence of counter-irritation and its *modus operandi* can receive no more striking illustration than is given in the ulcerated duodenum following extensive yet superficial burns of cutaneous surface.

61. To every action there is an exact and equal reaction. This is a physical law and has no exceptions. In the case of the burn, the spinal trophic centers were paralyzed by the counter-irritation produced, and the nerves coming from those centers no longer performed their functions, while the parts to which they were distributed necessarily underwent atrophic changes. The intensity of the counter-irritation and the length of time it is continued controls *in toto* its therapeutic results. Over static electricity, as a means of producing counter-irritation, the operator has absolute control, both as to intensity and duration of application. Thus, with proper care and skill, he can in a few seconds produce a mild diffuse redness very agreeable to the patient; or the same area operated on, by changing the manipulations and conditions, can be subjected to any or every gradation of counter-irritation that can be produced by the skilful operator, pathological indications alone controlling his work.

62. Modification of Functions.—The amount of blood imprisoned in the artificially congested area by a sinapism, or the amount of serum withdrawn from the general circulation by a blister, counts but little in the sum total of the beneficial and curative effects of these two agents. Much more consoling to the physician are the results demonstrated by Dr. Hodges. In a

series of careful experiments this investigator proves that impressions made on the peripheral endings of the sensory nerves are transported to the central ganglia, and are capable of producing there organic changes. This seems to be the pivotal point upon which must ever rest the physiological therapeutics of counter-irritation. The point which is of interest to the physician and which he should always remember is that central ganglia may be modified in their functions and changed in their organic structure by impressions made on the superficies of the body.

63. The results demonstrated by Dr. Hodges make it easily understood how friction and sparks operate in arresting the march of degenerative cord diseases. They make clear the *methodus medendi* of electricity, in all varieties of reflex pains, no matter what may be the direct cause of irritation. The reddened skin and the wheal-like and papular eruption are but superficial manifestations of the effects produced by electric energy. Beyond the skin, and within the central ganglia, spinal or cerebral, enduring changes are apparently established, which determine the real value of static electricity in daily practice. No amount of discussion on electrotechnical theories can alter the value of this now demonstrated fact, and the physician administering static electricity can feel himself secure on a physiological and rational therapeutic basis. It is the most important demonstration made since static electricity was first used for therapeutic purposes.

DOSAGE.

64. Regulation of Dosage.—With the static machine in full motion and a patient being treated, the physician habituated to the use of galvanism and faradism at once observes the absence of rheostats and meters. Without these means, how is the dosage of static electricity regulated? It depends much on the technique of the given application.

65. The static dose may be increased by the following means:

1. The electrical output of the static machine varies with the rapidity of the revolutions of its plates. The faster the plates revolve, the greater will be the electrical output. The rapidity of the revolution of the plates is regulated through the rheostat in the circuit, when a motor is used to run the machine. 175 ohms will be sufficient to regulate the motion of an 8-plate 30-inch machine, allowing all conceivable gradations from the slowest movements to racing motions. If turned by hand, the rate can be controlled still more easily.

2. The dose is further regulated by the means employed to conduct the electricity from the prime conductor to the patient. The least energetic manner of conducting the electricity to the patient on the insulated platform is by placing the platform-rod on a part of the platform as far removed as possible from the patient. In this way much of the current is wasted in traversing the wooden surface before it reaches the patient. The waste of current produced in this manner can be easily verified by requesting the individual on the platform to approach his finger to the prime conductor with which the platform is connected. If there is no current waste, no spark will pass between the patient's finger and the prime conductor. If a spark passes, it demonstrates a difference of potential and a consequent waste of current.

66. Direct Metallic Conduction.—The best means of conveying an electric charge from the prime conductor to the insulated patient is by means of direct metallic conduction. This may be done in one of two ways; viz., the patient holds the platform-rod attached to the prime conductor in both his hands, or the patient's feet may rest on a metallic electrode, which is attached by means of a chain to the connecting-rod resting somewhere on the platform. Either of these two methods constitutes direct metallic conduction, and is the surest way of giving to the patient the entire electric output of the machine.

Without direct metallic conduction, the dosage may be slightly increased or diminished by approaching or withdrawing the platform-rod to or from the patient. Office furniture

placed too near the platform will attract the current and thus diminish the charge. In the hot, damp days of summer, the plates and interior mechanism of the static machine should be kept thoroughly dry. This is best done by frequently rebaking the calcium chlorid. The atmosphere of the office may be dried of moisture by lighting a few gas-jets or by closing the windows and keeping a fire burning for an hour or two.

67. Use of Leyden Jars.—Only those skilled in the technique of static electricity should employ Leyden jars to increase the current. An accident might easily happen with the Leyden jars in unskilled hands, which would detract much from the reputation of the operator. The breeze, spray, and frictional spark may be increased in energy by interrupting the current between the prime conductor and the patient. This is best done by the patient holding one end of the platform-rod in his hand and resting the other end on the case of the machine, so that the rod is about $\frac{1}{2}$ or $\frac{3}{4}$ of an inch from the sliding-pole. This will cause a spark to pass between the platform-rod and the sliding-pole. This is the most efficient and at the same time the simplest way of increasing the strength of local and general static applications.

68. Mild Application of Spray.—The mildest breeze or spray application is made in the following manner: The patient is insulated negatively or positively, and the operator simply holds the metallic part of the electrode in his hands without any connection with the earth, and bringing it to the necessary distance from the patient. In this way a very mild spark may be administered, but each spark will cause a contraction in the operator's wrist. The strength or energy of the breeze, spray, or spark may be diminished by any of the following means:

1. The operator may leak off some of the charge through his foot, placed for the moment on the platform.
2. The machine may be made to run more slowly.
3. The metallic connecting-rod may be taken from the hands of the patient and placed upon the platform.

4. The farther the rod is placed from the patient's feet, the less energetic will be the spark, spray, or breeze.

In continuous-current administration, direct metallic connection with either hands or feet does not in the least annoy the patient, and the maximum current is thereby obtained.

69. Essentials of Static Dosage.—The essentials of static dosage may be regulated to a nicety by attention to the following details :

1. The rapidity of the revolution of the plates, whether slow, medium, or fast, must be carefully noted.
2. The condition of the atmosphere, both within and without the static case, is a matter of importance.
3. The calcium chlorid should be comparatively dry.
4. The means employed to convey the electric charge from the prime conductor to the patient should be considered.
5. If the conduction is indirect, regulate the distance between the patient's feet and the conducting-rod.
6. Keep surrounding objects at a distance that will not attract the current.
7. Remember that *accumulation* of current is a *sine qua non* in successful static therapeutics, and that every detail that fosters it should receive studious attention.

APPLICATION OF STATIC ELECTRICITY IN DISEASE.

70. Limitations.—To advocate the use of static electricity in all diseases brings one within the realm of charlatanism. To write that static electricity may be beneficially and appropriately employed in some stages of every disease or injury puts the question on a strictly clinical and demonstrable basis, and the assertion can be supported by anatomico-physiological researches. The great additional factor, the advantage afforded in its general use, allowance being made for its wonderful therapeutic properties, is that all treatment may be given without the patient removing any of his or her clothing. Every practitioner that has had any experience in electrotherapeutics knows the time consumed in, and the

embarrassment connected with, every general galvanic or faradic application. When the patient is in possession of all his faculties, mental as well as physical, disrobing may be conveniently resorted to, but when mental and physical disabilities are present, the act of disrobing, besides the time consumed, well-nigh counterbalances the value of general faradization. Static electricity, therefore, is the only current suitable for general office practice and *general* treatment, but owing to the height and size of the machine it is not portable, and this confines it to the physician's office; the patient must always be able to go to the machine—the machine, at least at present, cannot go to the patient. This fact excludes a large class of diseases from the benefit of static treatment.

71. Acute infectious fevers, contagious diseases, and, in general, all maladies requiring rest and recumbency, do not however come within the domain of static therapeutics. Its great field of use is found in functional nutritional diseases, in controlling the nervous, the circulatory, the respiratory, the muscular, the secretory, and the excretory system, and as a regulator of function and a distributor of harmony. These functional nutritional derangements may be either acute or chronic; they are both amenable to static treatment. Each operator will find it necessary to study the mechanism and adjustment of the machine he purchases before he can expect to obtain from it its best therapeutic work. Before a new machine settles down to steady and efficient work, it will need to be carefully adjusted and regulated. The physician expecting efficient work from his static machine must give it the same scrupulous care that he would give to any other machine or being from which he expected certain work. Indeed, static electricity and the mechanism that excites it ought to be considered separately.

72. Practical Uses of Static Electricity.—What, then, are the practical every-day uses of static electricity?

1. It gives tone and nutrition to sluggish, wasted, or atrophied muscles.

2. It regulates nerve action, either as a sedative or as a stimulant.

PLATE VI.

Positive Electrification.

3. Reflex pains, no matter how produced, are relieved or cured.

4. As a sedative and stimulating tonic it may be beneficially employed in many debilitated conditions, such as malaria, nervous exhaustion, prebacillary stage of tuberculosis, and in cases of simple anemia. After all major operations, and in convalescence from all diseases, static electricity is an invaluable therapeutic agent. In a physician's office it will illuminate a Crookes tube more brilliantly than any other means of electric excitation. In this way, fractures, dislocations, and various diseases of the bony framework may be continuously and scientifically studied. An osseous tumor, in its evolution, may be thus watched from week to week, and its increase of growth noted.

5. Muscular pains of rheumatic or traumatic origin, no matter where situated, are readily treated and quickly relieved. Thus, sparking or friction will speedily relieve recent lumbago or any other form of muscular rheumatism.

6. *The different local methods—spark, spray, or breeze—have different local action, according to the conditions present and the manipulations of the physician.*

73. High-Potential Currents.—Beyond these local effects the ever-present and valuable effects of high-potential high-frequency currents must not be forgotten. Metabolism of tissue is increased by every static treatment from 20 to 40 per cent. The amount of uric acid excreted is diminished, and the amount of carbonic acid, water, and urea increased. This amounts to saying that the demand created in the tissues for oxygen increases the oxidizing processes of the body from 20 to 40 per cent. The perturbatory action of the thick percussive spark, the counter-irritant and rubefacient effects of the short friction-spark, have been before described. Theoretically, the indications for the uses of static electricity are as wide as the range of disease itself; but, *in practice, the disease, the patient, and the static machine must all be considered*, and it is only when all these are in harmony, and able to cooperate to attain a given end, that the physiological and therapeutic properties of static

electricity are exhibited at their best. The short road to learn how to get the best results is to carefully study the technique illustrated and described in this Paper. The method of self-treatment is particularly recommended to the student.

74. The use of static electricity as the best agent to illuminate a Crookes tube, the facility that static electricity offers for general electrification without disrobing and without any discomfort whatever, must give to the static machine in the very near future a much wider popularity than it now commands, and it only lacks use now where it is not known.

DURATION AND FREQUENCY OF TREATMENT.

75. The average length of treatment in methods producing *general electrification* is from 10 to 15 minutes. The duration of any form of local application depends on getting the effects desired. Stimulations and counter-irritant applications are usually very short, and these effects are often obtained in from ½ minute to 2 minutes. Tonic applications are of medium length, while sedation must nearly always require a longer treatment. The length of time also varies with different cases, so that the sole rule of practice is to get the desired effect before closing the séance.

In acute or painful diseases a daily treatment is advisable until improvement permits a longer interval. In most chronic diseases the rule is three treatments per week.

CONCLUSION.

76. Action and Effect of Methods.—In the foregoing pages are described the standard methods of employing static electricity. In therapeutic administration these methods must be directed to produce *effects* that will represent indicated therapeutic actions. For instance, a "negative static breeze" may not treat any disease *per se*, but "counter-irritation" produced by means of the negative static breeze may be as effective treatment as any other form of counter-irritation. The student therefore should study the methods described in this Paper,

with a view to mastering the effects that each method can be caused to produce by proper variations in technique, for the Paper on Therapeutics of Static Currents is written from the standpoint of *the action and effect of methods*.

77. Franklinic Interrupted Current.—In order to complete the description of the therapeutic capabilities of a static machine, it is thought necessary to here add a description of the "Franklinic Interrupted Current," which was first enunciated by W. J. Morton, M. D., 1881. The principle of this current consists in interrupting the circuit at a point remote from the patient. Interrupting the circuit at this point is already familiar to the student in the description of "potential alternation," a form of static treatment first described by S. H. Monell, M. D., in 1893. Potential alternation, as described by its author, is simple electrification with patient and interrupter in the same circuit. The therapeutic value of this form of treatment has already been described. It is a general treatment, the body of the patient being submitted to the action of a rapidly interrupted oscillating current. The pistol electrode of Dr. Morton was devised for the same purpose, i. e., to interrupt the circuit remote from the patient.

The superiority of potential alternation as a method of general treatment is very easily demonstrated. As already stated, it increases the energy of simple positive electrification, and every organ of the body is under the influence of this rapidly interrupted oscillating current.

78. The Spark-Gap.—The spark-gap is adapted in length to the comfort of the patient, and the physician may go on with other business, or occupy himself with the treatment of other patients with either the galvanic or the faradic current. In this treatment by potential alternation, the negative pole of the static machine is grounded, and the electrode fixed in the movable stand is also grounded. The positive prime conductor is connected with the platform. The head-electrode is connected with the negative pole and is therefore grounded. If the question is asked, What is the principle of potential alternation? the answer is, The current is broken at a point

remote from the patient. The cuticle is not disrupted, and the disadvantages of sparks applied directly to the skin, such as burning, tingling, pain, and shock, are entirely removed. The sparking takes place between the ball of the electrode fixed in the movable stand and the terminal of the positive prime conductor. The spark-gap is easily regulated, and, once adapted to the comfort of the patient, it requires no more attention.

79. W. J. Morton's Treatment.—If, however, it is desired to act locally on any given part, as, for example, on the facial nerve, or the muscles of the face, other technique must be resorted to. Here the static induced current first described by W. J. Morton, M. D., in 1881, fulfils every indication. In this induced current, the interrupter is in the primary circuit and the patient is in the secondary circuit. The spark-gap is produced by separating the discharge-rods of the primary circuit. This acts like the interrupter in the primary circuit of an induction-apparatus. At each make and break in the primary circuit, a current is sent through the rheophores attached to the outer coatings of the Leyden jars, and through whatever part of the patient's body that may be included in the circuit. Like the current from the induction-coil, this static induced current is distinctly an alternating current, and is much employed at the present time by gynecologists in maladies of the pelvic viscera. The essential point for the physician to remember is that when he is using the static induced current he is using an alternating current of high potential and great frequency.

80. Methods Pursued.—In the system of treatment described by W. J. Morton, M. D., two distinct methods are made use of. In the first method the patient and interrupter are in the same circuit and the current that the patient receives is oscillating. In using this method, condensers may be employed. In the second method, which completes his system of administering Franklinic interrupted currents, the patient is in one circuit, the secondary circuit, and the interrupter is in another circuit, the primary circuit. Leyden jars constitute an essential feature of this method, and the patient treated is

submitted to an alternating current. In the first method, with or without Leyden jars, the current is oscillating; in the second method, Leyden jars are essential; the patient is in the secondary circuit, and the current is alternating. To use this static induced current in pelvic diseases, the unipolar method is employed. These electrodes will be illustrated in the Paper on *Electricity in Gynecology.*

The Goelet bipolar vaginal electrode, so admirably adapted to the use of coil-currents, will not suit for making applications of the static induced current, because the voltage of this current is so high as to overcome the resistance between the contact-cylinders or poles of the electrode.

81. Alternating Electromotive Forces Produced. As pointed out by Dr. Leduc,* static machines can produce a variety of alternating electromotive forces for medical uses. It can produce alternating electromotive forces of high tension and great frequency, analogous to those derived by Nicolas Tesla from other methods. The current that this alternating E. M. F. produces can illuminate conductors, give showers of sparks, and light lamps within the electric field by contact or at a distance. In order to obtain this alternating current of high tension and great frequency from the static machine, Leyden jars are essential. The static machine is short-circuited, and rheophores with electrodes at one end are connected by the other end to the external surface of the Leyden jars. By separating the discharge-rods of the static machine, a series of sparks pass between them, and an alternating current of high tension and great frequency is made to traverse the rheophores and the part of the body included in the secondary circuit.

By means of this static induced current, every muscle in the body, with the exception of those of the head and face, can be contracted energetically and without pain. The sparking between the terminals of the discharge-rods causes some annoyance to nervous patients. If it does not annoy the patient, it annoys the physician. To obviate this, the rheophores

* Bulletin of the Electrotherapeutical Laboratory of the University of Michigan, January, 1894.

connected to the external surface of the Leyden jars should be carried along the wall and into an adjoining room, where they are attached to appropriate electrodes. In this case a rheostat becomes essential.

82. The physician, after having set the static machine in motion, can separate the terminals of the discharge-rods to the distance he thinks necessary. He then regulates the current by means of the rheostat placed on a table beside the patient. It is clear that this gives the patient more privacy, and removes him or her from the noise of the spark. It also enables the physician to regulate the current he is using without interfering with the discharge-rods. The rheostat dispenses with the use of an assistant, and the physician is not obliged to run from patient to machine in order to regulate the strength of the application. The foot-bath electrode is often used in this form of static application; the placing of the other electrode necessitates more or less disrobing, hence the propriety of an adjoining room and the necessity of a rheostat. Dr. Cleaves has devised a rheostat that fulfils every indication in this form of treatment.

PHYSIOLOGY

OF

DIRECT CURRENTS.

PHYSIOLOGY OF DIRECT CURRENTS.

INTRODUCTION.

1. Scope of Subject.—Electrophysiology is divided into two parts, viz.: (1) the study of animal tissues or organs as sources of electricity, (2) the study of electricity as it modifies the irritability and influences the functions of animal tissues or organs. The phenomena of animal electricity have been the subject of much experimental investigation. It is likely that all tissues or organs that are the seat of active nutrition give rise to electric currents. The electricity coming from the electric organs of the gymnotus, or torpedo, and that set in motion by chemical action in a voltaic couple are in no way different. Indeed, the formation of the electric organs of these fish bears a marked resemblance to the artificial voltaic pile; both attract and repel, deflect the needle of a galvanometer, give shocks, and decompose compound bodies held in solution. In examining animal tissues for electric currents, non-polarizable electrodes and a delicately constructed galvanometer are used. Connect the longitudinal and transverse surfaces of a fresh piece of exsected muscle (muscle-prism) with the terminals of galvanometer-wires; the needle is at once deflected, demonstrating the passage of an electric current, also its strength and direction. By the deflection of the needle, the current is shown to flow from the longitudinal surface through the galvanometer to the transverse surface and back to the surface of origin. The longitudinal surface is therefore positive to the transverse surface. This current is known as the *current of rest.* While the current is flowing through the galvanometer, if by any means the muscle is caused to contract, the galvanometer-needle returns to zero. This is known as the *negative variation of muscle*, also as the *current of action.* A fresh piece of exsected nerve similarly arranged deflects the needle in the same direction (but not as

strongly) as the current from the muscle-prism. The electromotive force of the muscle-current is greater than that of the nerve-current. Stimulation of the nerve shows negative variation also, or current of action. The cause of these currents is not yet satisfactorily determined. Dubois-Raymond regarded them as a vital phenomenon, subordinate to the vitality of tissues and ceasing with their death. Herman attributes them to the mode of preparation of animal tissues, to trauma, or chemical action, to the difference of potential created between dying and living tissues.

2. Herman's Propositions.—Herman explains all the galvanic phenomena of living tissnes by the following propositions:

1. Localized death in continuity of protoplasm, whether caused by injury or metamorphosis (mucous, horny), renders the dead part negatively electrical to the unaltered part.
2. Localized excitation in continuity of protoplasm renders the excited part negatively electrical to the unaltered part.
3. Localized warming in continuity of protoplasm renders the warm part positive; localized cooling renders the cold part negative to the unaltered part.
4. Protoplasm is strongly polarizable on its limiting surfaces (first shown, as regards the protoplasm, to be enclosed in tubes of muscles and nerves); the polarization constantly decreases on excitation and on dying.*

PHYSIOLOGY OF NERVOUS SYSTEM.

MOTOR NERVES.

3. Physiology of Motor Nerves.—Electric irritation of a motor nerve manifests itself in an altered condition of the irritability of the nerve and in contraction of the muscles supplied by the nerve. A current of moderate strength applied gradually to a nerve does not produce muscular contraction. The continuous steady flow of a moderate galvanic current

* "Translation of Foreign Biological Memoirs." Edited by Burdon Sanderson.

through a motor nerve does not cause contraction in the muscles to which the nerve is distributed. The continuous flow of a strong galvanic current through a motor nerve will tetanize the muscles to which the nerve is distributed. If, however, the current of moderate strength is suddenly made or suddenly broken, the muscles are contracted. It is, therefore, as much the rapid change in current-density, the rapid change from zero to maximum current-strength, and from maximum current-strength to zero, as the actual current-density at any given time, that determines muscular contraction.

IRRITABILITY OF MOTOR NERVES.

4. Electrotonus, Anelectrotonus, and Catelectrotonus.—The place where an electric current enters a motor nerve is called the *anode*, and the place where it leaves the nerve is called the *cathode*. A galvanic current passing through a motor nerve produces changes in the irritability of the nerve. This changed state of irritability is known as *electrotonus*. That part of the nerve beneath and for some distance beyond the anode is in a condition of *anelectrotonus*, and that part of the nerve beneath and for some distance beyond the cathode is in a condition of *catelectrotonus*. About midway between anode and cathode the nerve irritability remains unchanged. If, while the galvanic current is passing through the nerve, its irritability is tested by chemical, mechanical, or electrical stimuli, it will be found to be increased in the catelectrotonic area and diminished in the anelectrotonic area. Catelectrotonus, therefore, means increased irritability, and anelectrotonus means diminished irritability.

5. Nerve Stimulation.—A nerve is said to be *stimulated* when its irritability is increased. Catelectrotonus is then a stimulant to the nerve. When anelectrotonus, or diminished irritability, disappears, the nerve returns to its normal condition. Disappearing anelectrotonus increases nerve irritability, and is also a stimulant to the nerve. Stimulating a motor nerve stimulates the muscles to which it is supplied. Disappearing catelectrotonus and appearing anelectrotonus

diminish the irritability of a motor nerve and do not stimulate the nerve. If both electrodes are placed on the bare sciatic nerve of a frog and the galvanic current turned on, a contraction of the muscles supplied by the nerve will take place when the current is closed with the cathode and when it is opened with the anode. It will be further observed that, with the same strength of current, closing with the cathode will produce a stronger contraction than opening with the anode. Appearing catelectrotonus is *per se* a stronger stimulus than disappearing anelectrotonus. The physiologist, therefore, with both electrodes on the bare nerve, obtains two contractions. One is produced by closing with the cathode, and the other by opening with the anode. Closing with the anode or opening with the cathode diminishes nerve irritability, and produces no effect on muscles.

6. Pfluger's Laws.—In studying this experiment with both electrodes on the bare nerve of the frog, it will be observed: (1) that the whole current passes through the nerve from the anode to the cathode, and that there is no loss of current from diffusion; (2) that for each actual anode there is but one virtual anode, and for each actual cathode but one virtual cathode; (3) that the electric current produces two zones, one anelectrotonic, and the other catelectrotonic.

From this experiment, Pfluger deduced the following laws:

Weak currents ascending or descending cause contractions on closure alone. Closure of ascending current produces stronger contraction than closure of descending current. The irritability of a motor nerve increases from periphery to center. Moderate currents produce contractions on opening and closing and in both directions, the closing contraction being the stronger. Very strong currents produce contraction on opening with the ascending current and on closing with the descending current.

These laws are supported by experimental proof, and are easily verified. *The galvanic excitation is purely polar, and is propagated from the polar area.* In order to understand the normal polar formula of the motor nerve of man, it is essential to keep in mind the polar nature of galvanic stimulus.

MOTOR-NERVE REACTIONS.

7. Motor Nerve of Man.—The response of a human motor nerve to electric stimulation is somewhat more complicated than that of the nerve of a frog. The cause of this difference is found in the different physical conditions of the nerves at the time the electrical test is made. The human nerve is covered by the skin, and is embedded in tissues having higher conducting powers than it possesses. Muscular tissue is a much better conductor of electricity than nerve tissue. The result is that the electric current, in obedience to the law of divided currents, takes the path of least resistance.

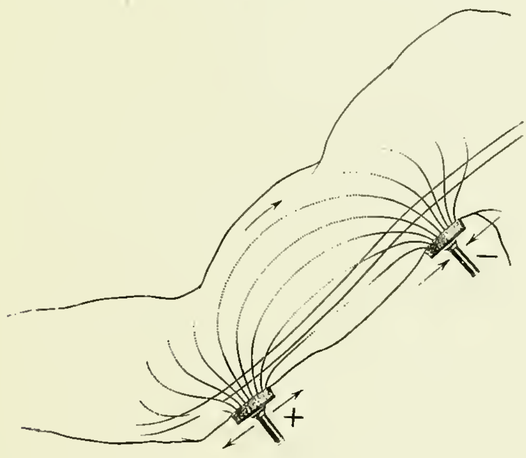

Fig. 1.

Directly on entering the nerve, it leaves and passes along the surrounding better conductors. When, therefore, a current is applied to a human nerve, two zones of opposite signs are produced beneath each electrode. Fig. 1 illustrates the various zones produced by the bipolar application of a current in the human subject. In order to avoid this confusion of zones, but one electrode is placed over the nerve in making an electrical examination of the human subject. The other, or indifferent, electrode is placed on the sternum, the nape of the neck, or some other convenient part of the body. The sternum

is the part usually selected. On account of the diffusion of the current, its direction is not considered. An examination of Fig. 2 will show that beneath the electrode the current has four different directions. The physiologist with both electrodes on

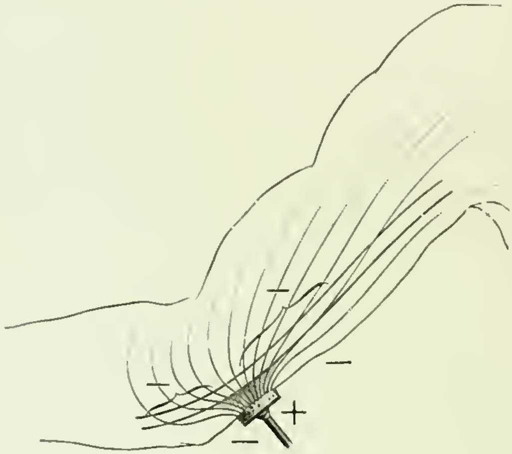

FIG. 2.

the bare nerve of a frog obtains two contractions, viz., *C C* and *A O*. When an electrode is placed over a human nerve and a current passes, it produces beneath and immediately around it two zones of opposite signs. Immediately beneath it, and of the same sign as the applied electrode, is the polar zone. Around this, and of opposite sign and greater area, is the peripolar zone. Each actual pole applied to the nerve produces two virtual poles of opposite signs. One electrode applied to

FIG. 3.

the motor nerve of man produces two zones of different irritability and density, the appearance and disappearance of which cause muscle-contraction. Each pole of the current produces two contractions, one on closing and the other on opening.

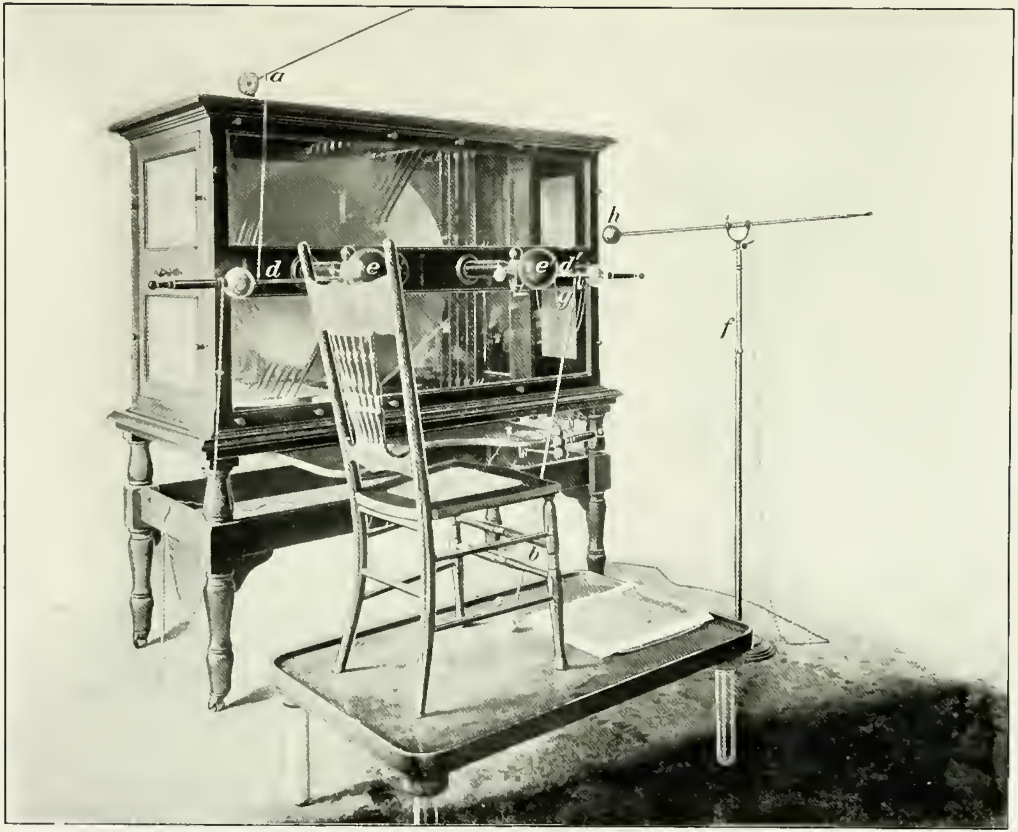

PLATE VII.

Potential Alternation.

These zones are shown in Fig. 3. In this figure, the anelectrotonic zone is represented by vertical lines and the catelectrotonic zone by horizontal lines.

8. Test for Electrical Reaction.—To test the electrical reaction of the motor nerves of man, it is necessary to have

FIG. 4.

a battery of twenty cells in good working order, with milliammeter, rheostat, and commutator in circuit. The electrode should be provided with a contrivance for interrupting the current. A suitable electrode-handle for interrupting the current is shown in Fig. 4. The standard electrodes of Erb are generally used. They are illustrated in Fig. 5. The electrodes are covered with wash-leather and thoroughly saturated with a

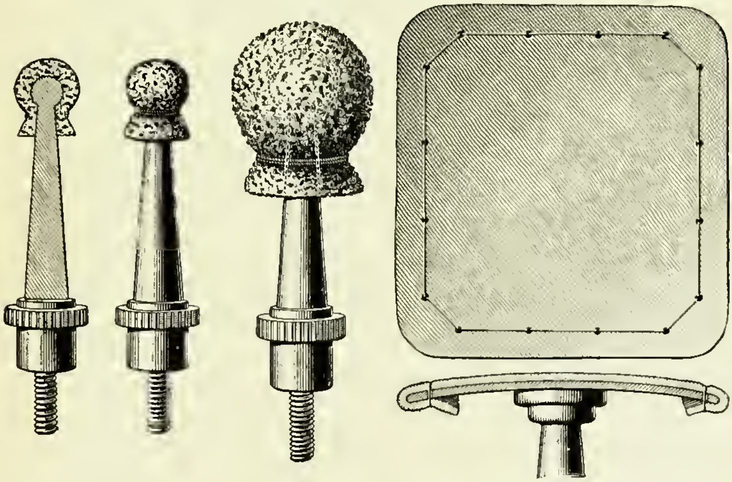

FIG. 5.

solution of bicarbonate of soda in water, one teaspoonful to the pint. Each time the electrode is applied it should be dipped in the soda solution. With the cathode on, say, the ulnar nerve, and the anode on the sternum, ascertain the number of

milliamperes needed to produce a minimal contraction on closing the circuit. With the commutator change the polarity, and ascertain the number of milliamperes needed to produce minimal contraction on opening and closing with the anode. The peroneal, the facial, and the spinal accessory nerves may be examined in the same manner. Cathodic closing contraction is always the first to appear. With a current twice as strong, anodic closing contraction is produced. Next in the series, and with a current a little stronger, comes anodic opening contraction. The last contraction to appear is on opening with the cathode, when cathodic opening contraction is produced. The current-strength necessary to elicit cathodic opening contraction is generally painful.

Different observers give different current-strengths for the production of minimal contractions at opening and closing with each electrode. The following current-strengths given by Dr. Verhoogen may be taken as those usually required:

CC—2 milliamperes.
AC—3 milliamperes.
AO—3.5 milliamperes.
CO—15 milliamperes.

These figures were obtained from tests on the ulnar nerve.

9. Normal Polar Formula.—The first contraction in the series is always on closing the circuit with the cathode, and the last on opening with the cathode, anodic opening and closing contractions appearing with intermediate current-strengths. The following is the normal polar formula for healthy motor nerves:

$$CC > AC > AO > CO,$$

in which $C =$ the cathode;
$A =$ the anode;
$O =$ the opening;
$C =$ the closing.

Fig. 3 explains the order of appearance of these different contractions.

Physiology teaches that appearing catelectrotonus is *per se* a stronger stimulus than disappearing anelectrotonus. The current-density is always greater in the polar than in the peripolar zone. The density of a current varies directly as its strength, and inversely as the area of its cross-section. Thus, beneath an electrode of 2 square inches the current-density would be twice as great as beneath one having a surface area of 4 square inches, the current-strength remaining the same. Cathodic closing contraction is caused by the stronger stimulus (appearing catelectrotonus) in the polar zone, or zone of greater current-density. This explains why it is always first in the series.

10. Anodic closing contraction is produced by the greater stimulus (catelectrotonus) in the peripolar zone, or zone of lesser density. Anodic opening contraction is a weaker stimulus (disappearing anelectrotonus) in a polar zone. Cathodic opening is a weak stimulus in a peripolar zone. Opening contraction for both poles is influenced by the duration of current-flow. *The longer the anode is closed on the nerve, the deeper the condition of anelectrotonus produced and the stronger the stimulus on opening.* The conducting power of the nerve is diminished in the anelectrotonic areas, and may, by sufficiently strong currents, be completely suppressed (physiological section). Voltaic alternatives stimulate a nerve more than simple interruptions, because the stimulus falls on the nerve with its irritability increased.

In order to make clearer the varying current-strengths required in eliciting the muscular contractions of the normal polar formula, and also the order of their appearance, the following table is given:

In the	*The Nature of Stimulus is*	*The Situation of Stimulus is*	
C C	Cathodic	Polar	= Best stimulus in best region.
A C	Cathodic	Peripolar	= Best stimulus in worst region.
A O	Anodic	Polar	= Worst stimulus in best region.
C O	Anodic	Peripolar	= Worst stimulus in worst region.

If this table is studied in conjunction with Fig. 3, the normal polar formula will be readily understood and easily remembered.

The columns of this table are read as follows: In the *CC* the nature of stimulus is cathodic, the situation of stimulus is polar; the contraction is therefore caused by the best stimulus in the best region.

FARADIC CURRENT.

11. Characteristics.—The induced current is a to-and-fro current, but for reasons given in *Magnetism and Electromagnetism* the effective current is in the same direction. While there is but little electrolytic action caused by the faradic current, its poles are physiologically different. If the anode is held in one hand and the cathode in the other, and the current started, it will be readily observed that the cathode has much the stronger action. Place one pole on the sternum and the other over the ulnar nerve, and start the battery in action. For every interruption in the current there will be a contraction of the muscles supplied by the nerve.

A slowly interrupted current causes contraction of the muscles at each break of the current. A rapidly interrupted current causes tetanic contraction of the muscles. This is because the muscle has not time to relax between each electrical stimulus to the nerve.

12. Action of Faradic Current.—The faradic current increases the irritability of motor nerves. Slow interruptions act like galvanic make-excitations. It is said that 19½ interruptions per second convert simple into compound contractions.

Fig. 6.

Motor nerves may be explored with the faradic current in the same manner as with the galvanic current. The different polar actions may be elicited and compared with one another. The strength of current at which contractions are obtained is measured on a scale that marks the distance of the secondary

from the primary coil. This is not by any means an exact method for measuring current-strength, but it serves, in a manner, for comparisons. A faradic battery with rheostat in primary and secondary circuit is best adapted for physiological and therapeutic use. The resistance in the circuit is then known, and with a given electromotive force the current-strength can easily be determined. The faradic current is generally employed in testing cutaneous sensibility. The electrode represented in Fig. 6 may be used for this purpose.

SENSORY NERVES.

13. Characteristic Reactions.—Nerves of sensation and nerves of motion respond to electric stimulus in much the same manner. A motor nerve when stimulated by an electric current causes muscular contraction. A sensory nerve will respond by sensation beneath the electrode, and in the area of distribution of the sensory nerve. A nerve of special sense will respond with a sensation corresponding to its specific function. The gustatory nerve responds with a sensation of taste, the optic nerve with a sensation of light, and the auditory nerve with a sensation of sound. Althaus states that he perceived an odor of phosphorus on stimulating his olfactory nerve. The cathode is more irritating to sensory nerves than the anode. In making an electrical examination of a sensory nerve, it is best accomplished by selecting a nerve without any motor elements. To obtain the normal formula of sensory nerves, the supraorbital is usually chosen. The galvanic current causes a sensation on each opening and closing of the current, and also during the continuous flow. With a weak current there is a sensation of pricking, which becomes burning on increasing the current-strength; while very strong currents produce pain. Part of these sensations is caused by the action of the current on the sensory nerve, and part is produced by the electrolytic action of the current.

14. Test for Reaction of Sensory Nerve.—To test the galvanic reactions of a sensory nerve, place one electrode,

well moistened, on the sternum, and the other small, or active, electrode over the nerve to be explored. Gradually turn on the current through the rheostat, closing and opening the circuit. Observe when the first sensation is produced. This will always be found to be on closing with the cathode. On increasing the current-strength with the anode over the nerve, there will be produced sensation on opening and closing with the anode. A stronger current is required to produce cathodic opening sensation. The normal polar formula for sensory nerves is therefore the same as that for motor nerves, namely, $C\,C > A\,C > A\,O > C\,O$. Each interruption of a faradic current produces a sensation like that of a galvanic make or break. With the galvanic current, the severity of the sensation increases with current-strength. The same is true of the faradic current. The greater the electromotive force and current-strength, the more pronounced the resulting sensation. With slow interruptions the individual shocks do not blend. When there are 100 or more interruptions per second, there is a benumbing or anesthetic effect produced in the nerve. A rapidly and smoothly interrupted faradic current benumbs the nerves and abolishes pain. Beneath 1,000 interruptions per minute, each induction-shock may be recognized. Sensitive points on the body should always be considered, so that they may be avoided on electrical examination.

15. Distribution of Sensory Nerve.—The distribution of a sensory nerve in a given area may be mapped out in the following manner: Move a very fine electrode with scarcely perceptible current-strength over the area to be explored. When the electrode is over a sensory nerve, the current will at once appear to be stronger. The benumbing anesthetic effect of the rapidly and smoothly interrupted coil-current is much used in daily practice.

The difference between the sensations caused by the cathode and anode depends on the size of the electrodes. If the anode is small and the cathode large, with the same current-strength, the sensation under the anode will be stronger than under the cathode. This is due to the difference in current-density, on

which the physiological activity of the current depends. The current-density varies directly with the current-strength, and inversely as the surface area of the electrode.

OPTIC NERVE.

16. The optic nerve reacts quite easily to the galvanic current. A weak current passed through almost any part of the head causes flashes of light. The faradic current acts but little, if any, on the optic nerve. To obtain the reactions of the optic nerve, place the indifferent electrode on the nape of the neck, and the small active electrode on the closed eyelid. The electrode represented in Fig. 7 is used to determine the reactions of the optic nerve. Through the rheostat gradually turn on one or two milliamperes, and open and close the circuit. Have the person examined describe the sensation that he perceives. Cathodic closing will produce the first sensation of light. The sensation produced by cathodic closing and anodic opening is qualitatively the same in the same individual. If cathodic closing produces a reddish light, anodic opening will also produce a reddish light, but in a feebler degree.

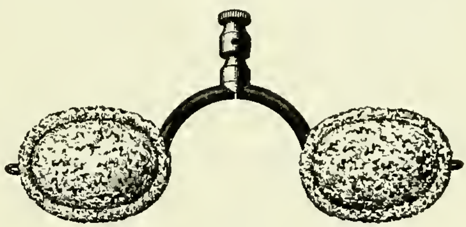

FIG. 7.

Cathodic closing and anodic opening stimuli fall in the same area (polar area), and thus produce the same sensations. Cathodic closing is *per se* stronger than anodic opening, and both of them are polar stimuli. Anodic closing and cathodic opening stimuli produce in the same individual the same color of light. Thus, if anodic closing produces a sensation of bluish light, cathodic opening will produce the same color. They are both stimuli in the peripolar zone. Cathodic opening and anodic closing produce qualitatively the same sensations. They both fall as stimulants in the same area,

viz., the peripolar zone. The normal polar formula for the optic nerve is as follows: $CC > AC > AO > CO$. It is not yet known whether these sensations are produced by stimulating the optic nerve or the retina.

AUDITORY NERVE.

17. Test for Reactions of Auditory Nerve.—To test the reactions of the auditory nerve, place a medium-sized well-moistened electrode over the tragus, and the other indifferent electrode on the nape of the neck. Turn the current on gradually through the rheostat, making and breaking it to obtain the polar reactions. The reaction of the auditory nerve is more difficult to elicit than are the reactions of the optic nerve. A greater current-strength is needed, and this often

FIG. 8.

produces disagreeable cerebral symptoms. The auditory nerve reacts according to the formula of the physiologist. It responds only to polar stimuli. There is a sensation of sound on closing with the cathode, and, if the current is strong, the sound continues during the flow of the current. The anodic opening sound is short and feeble. The normal formula for the auditory nerve is CC sound, CD (D meaning duration) sound, and AO feeble sound. The auditory nerve gives the polar action of the physiological experiment on the sciatic nerve of a frog. It responds to cathodic closing and anodic opening. This is due to the anatomical position of the nerve. It is surrounded with bone, and bone does not conduct electricity as well as

PLATE VIII.

Contracting Muscles of Arm by Interrupting Current at Terminal of Discharge-Rod.

a nerve. If there is a peripolar zone, the current is then so weak that no reaction is produced. The electrodes represented in Figs. 8 and 9 are used in testing the reactions of the auditory nerve.

18. Importance of Auditory-Nerve Reactions.—The reactions of the auditory nerve are very important from a therapeutic point of view. Tinnitus is a symptom of a large number of aural affections, and is amenable to treatment by the

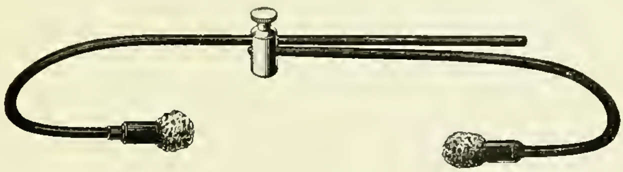

FIG. 9.

electric current. If the anode or cathode modifies or arrests the sound during the application of the current, the prognosis is favorable, and the treatment should be continued. In diseased irritable conditions of the auditory nerves, the reactions are much easier to obtain.

GUSTATORY NERVE.

19. This nerve reacts readily to the galvanic current. Flashes of light and galvanic taste are the usual accompaniments of every galvanic application to the head and neck. Place one electrode on each cheek, and turn on the current through the rheostat. Sensations of taste are experienced at both poles. The sensation is more marked at the anode than at the cathode. At the anode the taste is metallic; at the cathode, salty. The difference in taste at the two poles is so marked that it is easy to determine which is the anode and which the cathode. The sensation of taste continues during the passage of the current. It has not yet been determined whether this sensation of taste is due to the liberated acids and alkalis at their respective poles, or whether it is due to the action of the current on the nerves of taste or the end-organs.

OLFACTORY NERVE.

20. Stimulating the Olfactory Nerve.—The current-strength necessary to stimulate this nerve produces disagreeable central symptoms; such as flashes of light, vertigo, and nausea. For this reason the responses to stimulation of the olfactory nerve are difficult to observe. Ritter describes opening and closing sensations, and also sensations during current-flow. Althaus perceived a phosphorous-like sensation when his olfactory nerve was stimulated with a galvanic current.

In all applications of electricity to the head and neck, special care is necessary to avoid disagreeable accidents. The current should always be turned on gradually through the rheostat, and turned off with the same care and in the same manner. Do not change polarity during flow of current. Gradually reduce the current to zero, and then change the poles. When the current is applied to regions covered with hair, the hair should be thoroughly moistened, to diminish resistance to the current.

21. Percutaneous Applications to Head.—The percutaneous application of the galvanic current in bearable doses to the region of the head causes no observable effects on the cortical motor centers of the cerebrum. The faradic current has no direct action on the brain. When a galvanic current is passed in a longitudinal direction through the brain, a pricking sensation is felt beneath the electrodes, and a dull heavy sensation is experienced at the vertex. A current passed in the transverse direction causes vertigo, with a tendency to fall at the side of the anode. The more the current approaches to the transverse direction, the greater its capacity to produce vertigo. Nausea, vertigo, flashes of light, and galvanic taste are even produced by mild currents passed transversely through the brain. Medium-sized well-moistened electrodes are used in applications to the cerebrum.

22. Spinal Cord.—The knowledge of the action of galvanism on the spinal cord is very meager. All the phenomena observed, even when a strong current is used,

may be explained by the action on the motor roots. Whether the galvanic current acts on the ciliospinal center or the genitospinal center is still undecided. The induced current does not act on the spinal cord.

THE MUSCLES.

23. Striated Muscles.—The action of a galvanic current on striated muscles, when indirectly applied through the motor nerves, has already been described. Their response to direct electric stimulation is simpler than when stimulated through their motor nerve. On direct application, striated muscles react to closing stimuli, and the cathodic closing is stronger than the anodic closing. The formula for striated muscle reaction is $C\,C > A\,C$. When the motor end-plates are destroyed in cases of curare poisoning, the muscles contract somewhat slower than normal, and the contractions are prolonged. The faradic current contracts muscles in a direct application by stimulating the intramuscular nerve-fibers. *The reaction of striated muscles to faradism is identical, whether the electrode is applied to the nerve-trunk or directly over the muscle.* In the curarized nerve, the muscles respond to direct faradic stimulation. In conditions of health, however, and on the human subject, faradism produces muscular contraction by stimulating the intramuscular nerve-fiber.

24. Non-Striated Muscles.—The electrical stimuli from either current produces a wave-like vermicular contraction, which spreads from the point of stimulation. This wave-like contraction is slow in appearing, and continues after the stimulant is withdrawn. *Non-striated muscles are best stimulated by slowly interrupted galvanic currents.* A voltaic alternative constitutes the strongest electrical stimulus that can be given non-striated muscle-fibers. The reaction of non-striated muscles is slothful and tardy, resembling in this respect the reaction of degeneration. The percutaneous application of faradism produces a vigorous wave-like contraction of the non-striated muscles. Often, after a vigorous application, the bowels are evacuated.

The effects of the percutaneous application of faradism are well seen in cases of hernia. When the current is acting, the wave-like vermicular contraction can be easily seen through the hernia-sack. The direct application of galvanism *per rectum* by means of a water-electrode affords the best and most energetic means of stimulating the muscle-fibers of the intestines.

ELECTRODIAGNOSIS.

25. Scope.—This includes an examination of the electrical reactions of diseased nerves and muscles, and a comparison of the results thus obtained with the reactions of healthy nerves and muscles. In unilateral diseases, the sound and healthy parts are compared. The method of examination on the sound side should be carefully observed on the diseased side. When disease is bilateral, the electrical reactions obtained should be compared with those of some other nerves and muscles whose reactions are known to have nearly the same value. From experiments on a large number of individuals, Erb ascertained that the peroneal, ulnar, frontalis branch of facial, and spinal accessory nerves gave very nearly similar reactions to equal current-strengths. Any one of these four nerves may then be taken as a standard of comparison, when some nerve on both sides of the body is involved.

26. Method of Procedure.—Both currents are used in making electric diagnosis. A vessel containing a bicarbonate solution should be near at hand, so that the electrodes can be kept thoroughly moistened. The parts to be examined are freed from clothing, the muscles relaxed, and the skin well moistened. The active electrode is small and should not exceed $\frac{4}{5}$ inch in diameter. Wash-leather is the best cover for electrodes. The electrodes represented in Figs. 10 and 11 may be secured to neck or arm. They are self-retaining and give no trouble during electrical investigations. Begin with the faradic current, and first test the irritability of the nerve-trunk, noting the weakest current that induces the first visible muscular contraction. Next go over the motor points of the region. The

same process is repeated with the galvanic current. Make a note of the number of milliamperes needed to produce the first visible muscular contraction; also, note whether the pole that is placed over the nerve is cathode or anode, and whether it is at the opening or the closing of the circuit. The irritability of a nerve to both currents may be altered in two ways: it may be either increased or diminished. The irritability of the nerve is increased when the first visible contraction is caused by a current of less strength than normal; and it is diminished when a current stronger than normal is required to excite muscular contraction. Increased irritability of nerve to both currents is observed in the early stages of locomotor ataxia, in tetanus, and in chorea. To determine with certainty increased nerve irritability, the resistance of the skin over the parts explored must be accurately measured. If the resistance of the tissues over one nerve is more than that over the other, the current-strength necessary to contract the muscles must differ. The irritability of a nerve to both currents is diminished when a current-strength greater than the normal is required to produce the first visible contraction. Diminished irritability to both currents occurs in leucomyelitic diseases of long standing and in cerebral palsies in later stages. Its existence excludes shamming and hysteria. The changes in nerve irritability are then quantitative. There are no qualitative alterations in nerve irritability. Atrophies from disuse and from inflammatory

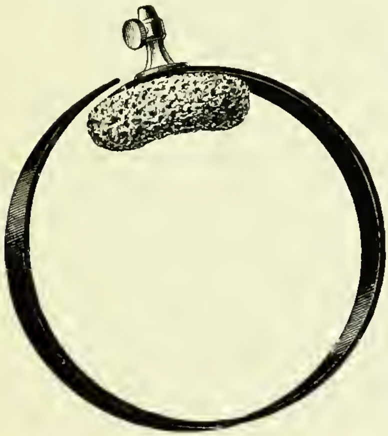

Fig. 10.

Fig. 11.

joint diseases are characterized by diminished nerve irritability. The determination of skin resistance is as important in diminished irritability as it is in increased irritability.

MUSCLE REACTIONS.

27. Quantitative and Qualitative Changes.—The muscle reacts to the faradic current in the same manner as it does to its motor nerve. The faradic current contracts muscles by stimulating its intramuscular nerve-fibers. To the galvanic current the alterations in irritability are both quantitative and qualitative. The quantitative alterations consist in increased or decreased irritability. The qualitative changes consist in changes in the mode of contraction, and in the relative order of polar contractions. There are no qualitative alterations to the faradic current, because the current stimulates the nerves. The qualitative changes in muscular irritability are serial and modal. The serial changes consist in a reversal of the normal polar formula. The anode takes the place of the cathode. The modal change is a change in the character of the contraction. Instead of the sharp lightning-like contraction of health, the contraction is tardy in appearing, sluggish, and prolonged.

REACTION OF DEGENERATION.

28. Nature of Reaction.—Reaction of degeneration in its complete form consists in (1) loss of nerve irritability to both currents; (2) loss of faradic muscular irritability; (3) gradual increase of galvanomuscular irritability; (4) serial changes, the anode taking the place of the cathode; (5) modal changes, the contraction being tardy, sluggish, and prolonged. This tardy, sluggish contraction is pathognomonic of degeneration, and in its absence degeneration should not be diagnosed. In partial reaction of degeneration, nerve irritability is preserved or may be somewhat diminished for both currents, faradic muscular irritability is intact or slightly diminished, while to galvanism the muscles respond with the serial and

modal changes of reaction of degeneration. In every case of partial reaction of degeneration, careful investigation will always disclose some alteration in nerve-reaction to the faradic current.

The existence of muscular degeneration, in its earliest stage, is best detected by static sparks. Next in diagnostic importance comes the rapidly interrupted coil-current. When both of these fail to produce muscular contraction, the slowly interrupted coil-current should be tried. As a last means in the exploratory diagnosis, the direct current is resorted to, and in its use the action of voltaic alternatives should be remembered.

29. Its Importance.—The importance of reaction of degeneration lies in its connection with degenerative changes in the neuromuscular area exhibiting its phenomena. When present, it always means nutritive disturbances in the nerves and muscles involved. It always points to a disease having a neurotic origin, the seat of which is in the ganglion-cells of the anterior cornua, in the nuclei of origin for the cranial nerves, in the nerve-trunks, or in the motor end-plates. It never occurs in purely cerebral palsies, unless the nuclei of origin for the cranial nerves are involved. It is never present in diseases of the white substances of the cord, unless there is secondary involvement of the anterior cornua. It is not present in atrophies of purely muscular origin, nor in atrophies from disuse, nor from inflammatory affections of joints, nor in hysteria. In cases of shamming, reaction of degeneration is necessarily absent. A hopeless case of hemiplegia of central origin may present normal electrical reactions for years. A case of facial paralysis exhibiting complete reaction of degeneration may get completely well within a year. From this it will be seen that there is no essential relation between the reaction of degeneration and paralysis. Normal electrical reactions depend on the normal function of the ganglion-cell of the anterior cornua of the spinal cord; or, they may depend on the nucleus of origin in the cerebrum for the cranial nerves, and also on the normal function of the motor nerves that communicate the influence of the ganglion-cell to the periphery. The presence

of reaction of degeneration means a disturbance in the nutrition of the motor track, beginning with the ganglion-cell in the anterior cornua, and including the motor nerve-trunk and motor end-plate within the sarcolemma. Partial reaction of degeneration is explained by Erb in assuming different centers of nutrition for nerves and muscles.

30. Partial Reaction of Degeneration.—Fig. 12 illustrates these centers and explains the phenomena of partial reaction of degeneration. In this illustration, the neurotrophic,

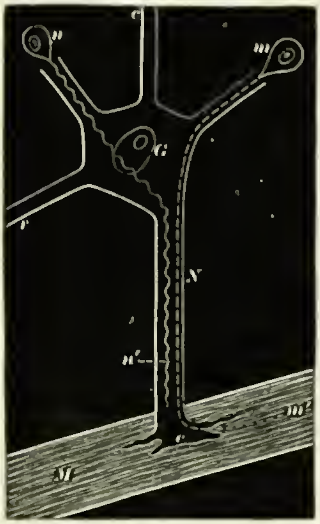

FIG. 12.

M, Muscular fiber.
N, Nerve-fiber, with its ending *e*.
G, Multipolar ganglion-cell, from the anterior horn of gray matter, or bulbar nuclei.
c, Path of impulse from the brain: anterolateral columns.
r, Path of reflex excitation from the sensory sphere.
m, "Trophic center" for the muscle.
n, "Trophic center" for the nerve.
m m', Path of trophic influence to the muscle.
n n', Path of trophic influence to the nerve.

myotrophic, reflex, and voluntary influences pass through the ganglion-cell *G*. Complete destruction of the ganglion, as in infantile paralysis, must be followed by degeneration in both nerves and muscles, and complete reaction of degeneration. Complete involvement of the trunk *N* would also produce complete reaction of degeneration. When *c* alone is diseased, there is loss of voluntary power in the muscle, but electroexcitability remains normal. There is no atrophy of nerve or muscle. This is a condition that exists in cerebral hemorrhage and in lateral sclerosis. If *M* alone is diseased, the myotrophic

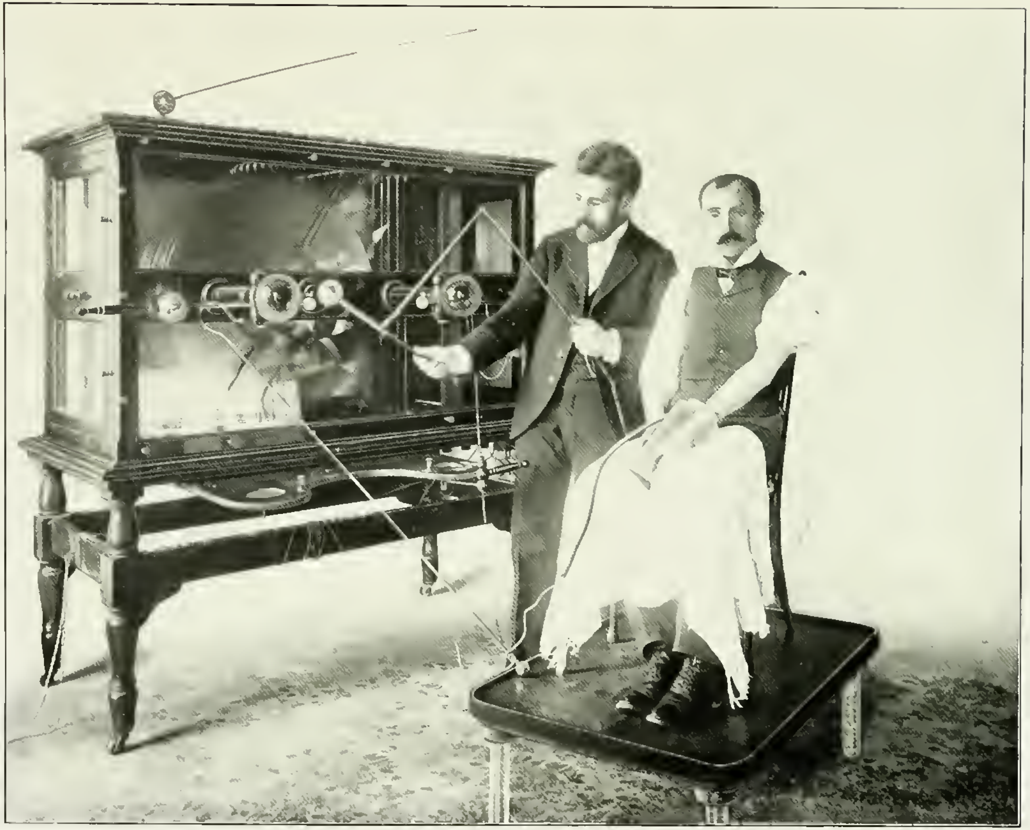

PLATE IX.

Static Interrupted Current—Hand-Bath Electrode.

influence of nervous tissue is cut off from the muscles, and as a consequence the muscles undergo degenerative changes. Electronervous excitability remains normal, but the muscles exhibit the serial and modal changes of reaction of degeneration. There is no paralysis. When *c* and *M* are both diseased, there is paralysis and atrophy of the muscles, electronervous excitability is normal, and the muscles exhibit reaction of degeneration. In severe forms of neuritis, rheumatism, alcoholic or toxic, *N* is destroyed, and there is present complete reaction of degeneration. In progressive muscular atrophy and bulbar paralysis, the lesion is generally located at *M*; the muscles are therefore atrophied, but not paralyzed. Electronervous excitability is intact.

31. Facial Paralysis.—In mild forms of facial paralysis, the electrical reactions are all normal, paralysis being the only symptom. In this case it must be assumed that the nerve-trunk is diseased in its capacity for carrying or propagating motor impulses. Fig. 12 supposes separate fibers in the nerve-trunk for conveying motor impulses, and myotrophic and neurotrophic influences. In lead palsies, the entire nerve-trunk is diseased, and there is complete reaction of degeneration. Where a single group of muscles is involved, the disease is generally confined to the nerve-trunk supplying the group. When groups of muscles, physiologically as well as anatomically connected, exhibit the phenomena of reaction of degeneration, the lesion is usually in the anterior cornua of the spinal cord. The study of the reaction of degeneration locates the seat of lesion; it seperates in a broad way certain diseases of spinal origin from diseases of cerebral origin. Its presence always excludes hysteria and shamming. Yet it must be remembered that grave spinal and cerebral lesions are often present, and are accompanied with normal or nearly normal electrical reactions. The study of reaction of degeneration does not give any aid in the etiology of disease. The disease may be due to pressure, to rheumatism, or to alcohol, and the presence of reaction of degeneration does not help in differentiating the cause of the disease.

32. Prognosis of Nervous Diseases.—A careful study of reaction of degeneration gives valuable information in forming the prognosis in nervous diseases. Erb points out that, in a complete facial paralysis with normal electrical reactions, the disease gets well in a few weeks. With partial reaction of degeneration present, the disease lasts a few months; and when reaction of degeneration is complete, the disease lasts six months, nine months, or longer. As a general rule, he states that the more complete the reactions of degeneration and the longer they have been manifest, the more unfavorable the prognosis; the etiology of the disease always, however, takes first place in forming a prognosis. It would be manifestly erroneous to give the same prognosis in reaction of degeneration due to rheumatic neuritis of the facial nerve, as in reaction of degeneration of the same grade due to tubercular disease of the petrous portion of the temporal bone. This same reasoning in forming a prognosis is applicable as strictly in the other nerves as it is in the facial. The prognosis is best made in studying reaction of degeneration in connection with the clinical history and etiological factors in the disease.

33. Disappearance of Excitability.—The disappearance of electronervous excitability coincides with the degeneration of the nerve structure. Farado-muscular excitability disappears with established degeneration of intramuscular nerve-fibers and motor end-plates. The serial and modal changes are due to pathological alterations in the muscle structure proper. When the disease does not get better, the muscle structure undergoes connective-tissue transformation and no longer responds to electrical stimulus. The last contraction to disappear is anodic closure. If regeneration takes place in the nerve, voluntary impulses are first transmitted, and this is shortly followed by conduction for electric stimuli. The muscles begin to respond more sharply, the sluggish contraction gradually disappears, and the cathode takes its normal position in the polar series.

34. Female Pelvic Diseases.—Within recent years electricity has been used for diagnostic purposes in female

pelvic diseases. Apostoli uses the galvanic current to determine the condition of the uterine appendages, and, if they are diseased, to determine to what extent. Intra-uterine galvanocaustic applications to the uterus cause febrile reactions in cases where the appendages are inflamed. The same is true of purulent collections. Galvanism has no beneficial effect on fibroid tumors that have undergone cystic degeneration, and may do harm. In this way, the careful use of the galvanic current will give much valuable information that cannot be obtained by any other method short of exploratory celiotomy. Serous cysts are not benefited by galvanism, and purulent inflammatory collections give febrile reactions.

35. Motor Points.—The motor points were first pointed out by Duchenne as those points on the surface of a muscle that responded most energetically to electrical stimulation. In his investigations, Duchenne used the electrodes shown in Fig. 13. They are metallic electrodes and when used the points should be covered with chamois. By experiments on the cadaver, Von Ziemssen subsequently demonstrated that these motor points correspond to the entrance of the nerve-fibers into the muscle. When the localized application of electricity was recognized as the chief method of treating disease, the motor points were of more importance than they are today. The situation of the motor points is best determined by using a fine electrode, well moistened. The accompanying illustrations from Von Ziemssen show the principal motor points of the body. It is recommended as good practice to locate these points by applications to one's own body. In this way, a knowledge of the sensations of the different currents is acquired, as well as the location of the motor points. After locating the motor points, they may be touched with nitrate of silver and photographed.

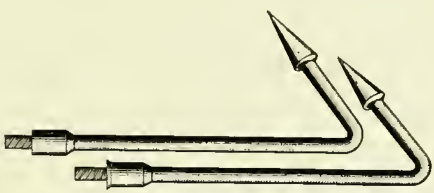

FIG. 13.

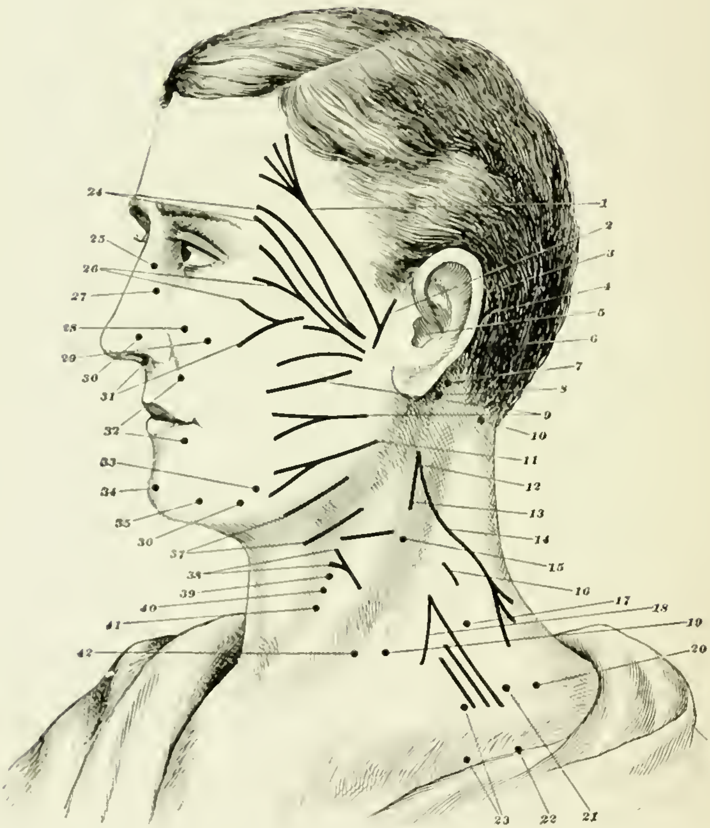
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

FIG. 14.

MOTOR POINTS OF HEAD AND NECK.

1, Frontalis muscle.
2, Attrahens and attollens auriculam muscle.
3, Retrahens and attollens auriculam muscle.
4, Occipitalis muscle.
5, Facial nerve.
6, Posterior auricular branch of facial nerve.
7, Stylohyoid muscle.
8, Digastric muscle.
9, Buccal branch of facial nerve.
10, Splenius capitis muscle.
11, Subcutaneous branches of inferior maxillary nerve.
12, External branch of spinal accessory nerve.
13, Sternomastoid muscle.
14, Cucullaris muscle.
15, Sternomastoid muscle.
16, Levator angulæ scapulæ muscle.
17, Posterior thoracic nerve.
18, Phrenic nerve.
19, Omohyoid muscle.
20, Nerve to serratus magnus muscle.
21, Axillary nerve.
22, Branch of brachial plexus (musculocutaneous and part of median).
23, Anterior thoracic nerve (pectoral muscles).
24, Corrugator supercilii muscles.
25, Compressor nasi and pyramidalis nasi muscle.
26, Orbicularis palpebrarum muscle.
27, Levator labii superioris alæque nasi muscle.
28, Levator labii superioris muscle.
29, Zygomaticus minor muscle.
30, Dilatator naris.
31, Zygomaticus major.
32, Orbicularis oris.
33, Branch to triangularis and levator menti muscles.
34, Levator menti muscle.
35, Quadratus menti muscles.
36, Triangularis menti muscle.
37, Cervical branch of facial nerve.
38, Branch to platysma muscle.
39, Sternohyoid muscle.
40, Omohyoid muscle.
41, Sternothyroid muscle.
42, Sternohyoid muscle.

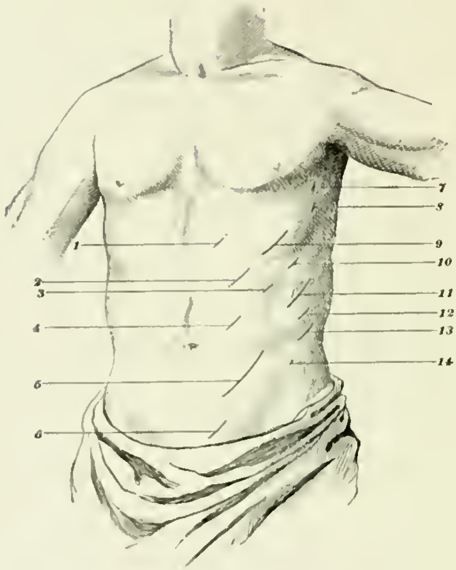

Fig. 15.

MOTOR POINTS OF ANTERIOR SURFACE OF TRUNK.

1, *2*, *3*, *4*, *5*, *6*, Rectus abdominis. (Intercostal nerves.)
7, Serratus magnus.
8, Latissimus dorsi.
9, *10*, *11*, *12*, *13*, Obliquus externus. (Intercostal nerves.)
14, Transversalis.

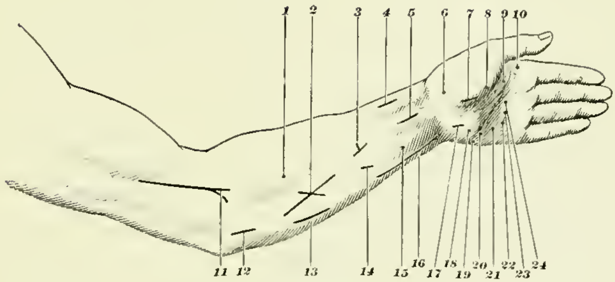

FIG. 16.

MOTOR POINTS OF FLEXOR SURFACE OF FOREARM.

1, Flexor carpi radialis.
2, Flexor profundus digitorum.
3, Flexor sublimis digitorum.
4, Flexor longus pollicis.
5, Median nerve.
6, Abductor pollicis.
7, Opponens pollicis.
8, Flexor brevis pollicis.
9, Adductor pollicis.
10, *22*, *23*, *24*, } Lumbricales.
11, Branch of median nerve to pronator teres.
12, Palmaris longus
13, Flexor carpi ulnaris.
14, Flexor sublimis digitorum.
15, Flexor sublimis digitorum. (Index and little finger.)
16, Ulnar nerve.
17, Deep branch of ulnar nerve.
18, Palmaris brevis.
19, Abductor minimi digiti.
20, Flexor brevis minimi digiti.
21, Opponens minimi digiti.

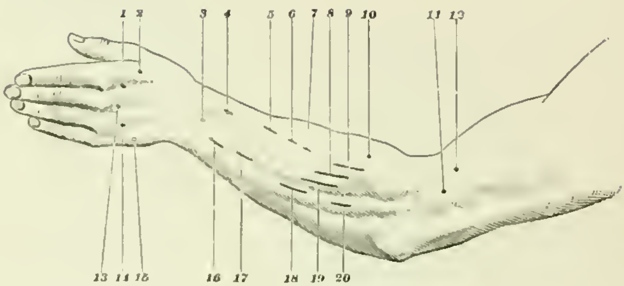

Fig. 17.

MOTOR POINTS OF EXTENSOR SURFACE OF FOREARM.

1, *2*, *13*, *14*, Dorsal interossei.
3, Extensor indicis.
4, Extensor primi internodii pollicis.
5, Extensor ossis metacarpi pollicis.
6, Extensor indicis et extensor ossis metacarpi pollicis.
7, Extensor indicis.
8, *9*, *19*, Extensor communis digitorum.
10, Extensor carpi radialis brevior.
11, Extensor carpi radialis longior.
12, Supinator longus.
15, Abductor minimi digiti.
16, Extensor secundi internodii pollicis.
17, Extensor indicis.
18, Extensor minimi digiti.
20, Extensor carpi ulnaris.

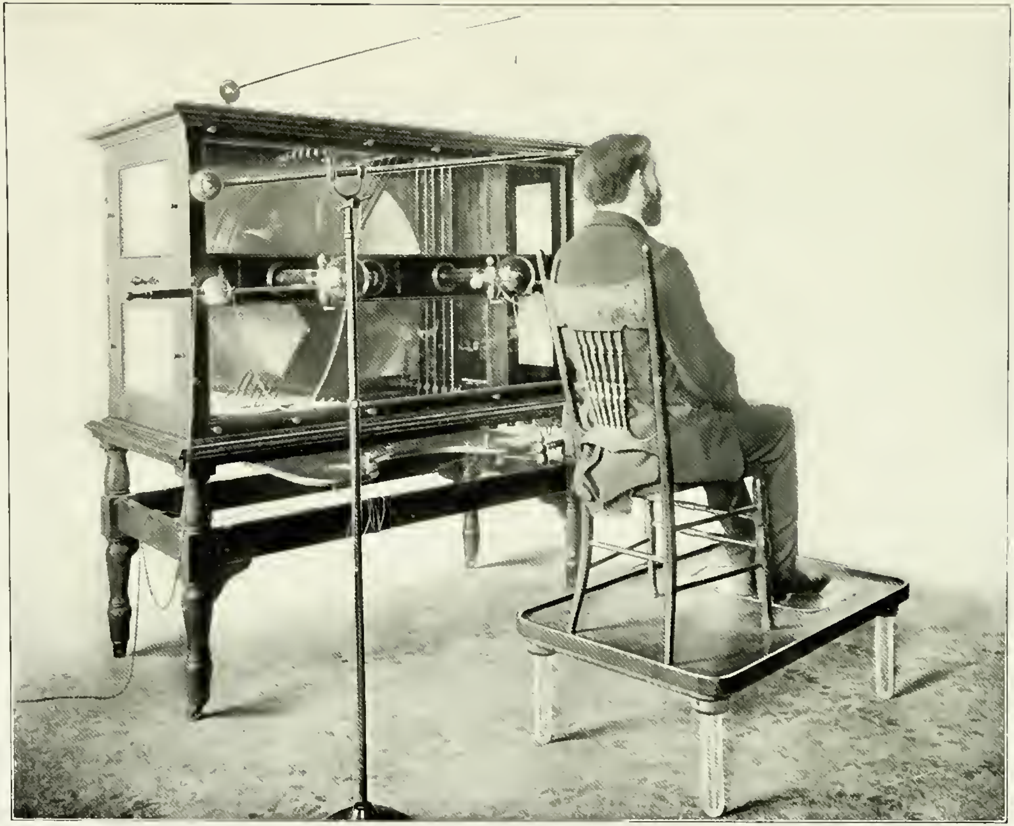

PLATE X.

Stationary Breeze to Occiput.

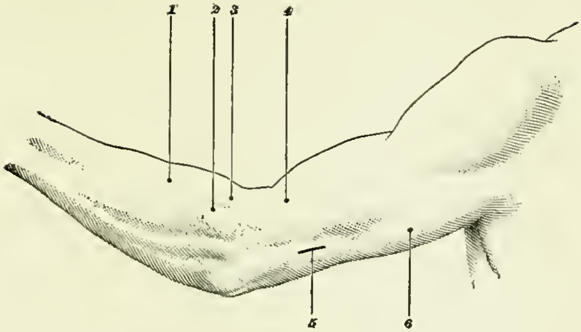

FIG. 18.

MOTOR POINTS OF POSTERIOR OR EXTENSOR SURFACE OF LEFT ARM.

1, Extensor carpi radialis brevior.
2, Extensor carpi radialis longior.
3, Supinator longus.
4, Brachialis anticus.
5, Musculospiral nerve.
6, External head of triceps.

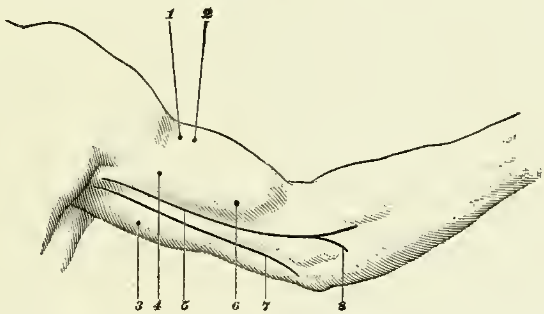

FIG 19.

MOTOR POINTS OF ANTERIOR SURFACE OF LEFT ARM.

1, Musculocutaneous nerve.
2, Branch to biceps.
3, Branch to long head of triceps.
4, Musculocutaneous nerve.
5, Median nerve.
6, Brachialis anticus.
7, Ulnar nerve.
8, Branch of median nerve to pronator teres.

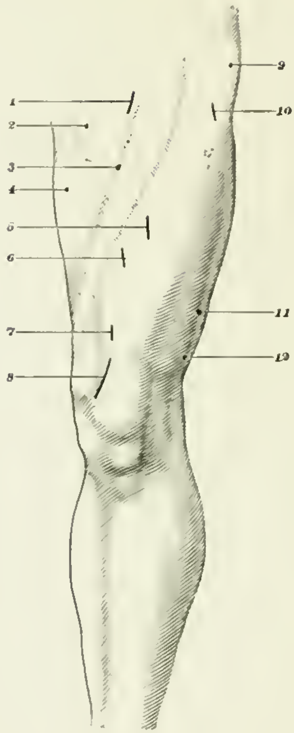

Fig. 20

MOTOR POINTS OF ANTERIOR SURFACE OF THIGH.

1, Cruralis.
2, Obturatorius.
3, Sartorius.
4, Adductor longus.
5, Rectus femoris.
6, Ram. N. cruralis pro M. quadricipis.
7, Cruralis.
8, Ram. N. cruralis pro M. vasto int.
9, Tensor fasciæ lat. (Ram. N. glutei sup.)
10, Tensor fasciæ lat. (Ram. N. cruralis.)
11, } Vastus extern.
12, }

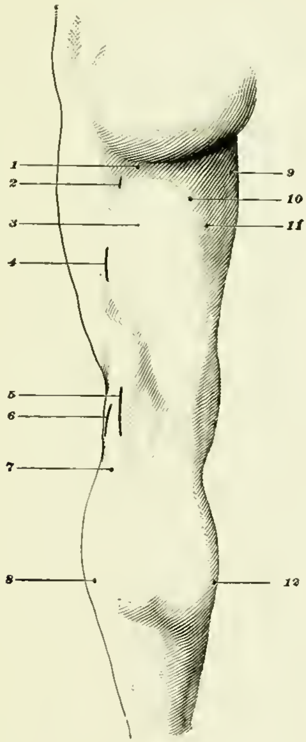

FIG. 21.

MOTOR POINTS OF POSTERIOR SURFACE OF THIGH.

1, Ram. inf. N. glut. inf. pro M. glut. maxim.
2, Sciatic nerve.
3, Long head of biceps.
4, Short head of biceps.
5, Tibial nerve.
6, Peroneal nerve.
7, Gastrocnemius externus.
8, Soleus.
9, Adductor magnus.
10, Semitendinosus.
11, Semimembranosus.
12, Gastrocnemius internus.

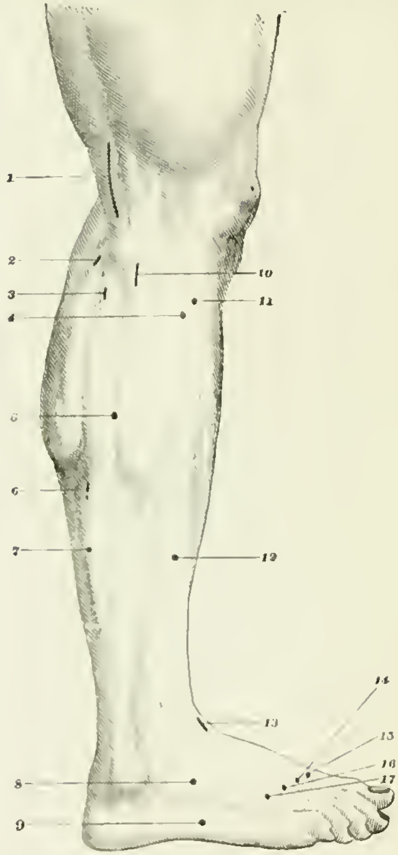

FIG. 22

MOTOR POINTS OF OUTER SURFACE OF LEG.

1. Peroneal nerve.
2, Ext. head of gastrocnemius
3, Soleus.
4, Extensor longus digitorum communis.
5, Peroneus brevis.
6, Soleus.
7, Flexor longus hallucis.
8, Extensor communis digitorum brevis.
9, Abductor minimi digiti.
10, Peroneus longus.
11. Tibialis anticus.

12, Extensor longus hallucis.

13, Ant. tibial nerve.
Extensor brevis digitorum.

14, *15*, *16*, *17*, Dorsal interossei.

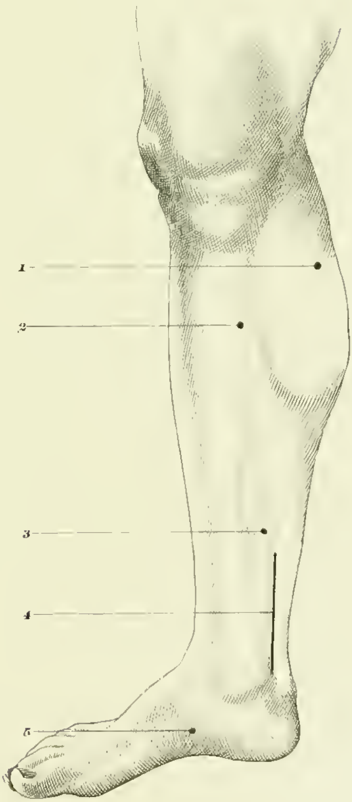

Fig. 23.

MOTOR POINTS OF INNER SURFACE OF LEG.

1, M. gastrocnemius internus.
2, M. soleus.
3, M. flex. digitor. commun. long.
4, N. tibialis.
5, M. abductor pollicis.

36. The following table by Dr. De Watteville is a guide to the seat of a lesion in the diseases of the nervous and muscular systems as far as it can be indicated by the electrical reactions:

(*A*) Normal	1. Healthy—shamming 2. Functional disturbance of 3. Organic disturbance of		Cortex. Corpus striatum. Peduncles. Pons. Lateral columns. Peripheral nerves { Very slight disease. Muscles.
(*B*) Abnormal	Quantitative alterations	Augmented irritability	Irritative processes in { Brain lateral column. Hyperexcitability in { Cornua nerve-muscle.
		Diminished irritability	Alterations in nerve-muscle of spinal origin. Alterations in nerve-muscle of idiopathic origin. Alterations in nerve-muscle of post-regenerative origin.
	Quantitative and Qualitative	Complete reaction of degeneration	Destruction of anterior cornua. Disease of multipolar cells. Disease of trophic centers of nerve-muscle. Severe lesion of nerve-trunk.
		Partial reaction of degeneration	Slight disease of multipolar cells. Disease of trophic centers of muscle. Slight disease of nerve-trunk.

37. Points favorable for the electrization of nerves.

In the upper limb:

1. The *median*, along the inner border of the biceps, and at the bend of the elbow.

2. The *ulnar*, in the groove between the internal condyle and the olecranon.

3. The *musculospiral*, at the point where it emerges from the triceps; namely, on the outer side of the upper arm, about the junction of its middle and lower thirds.

4. The *musculocutaneous*, between the biceps and coracobrachialis.

5. The *long thoracic* (serratus magnus), on the inner wall of the axilla.

6. "At a spot 1 inch above the clavicle and a little externally to the posterior border of the sternomastoid, immediately in front of the transverse process of the sixth cervical vertebra a simultaneous contraction can be produced in the deltoid, biceps, coracobrachialis, brachialis anticus, and supinator longus." This point has been called the supraclavicular point of Erb.

38. In the lower limb:

7. The *anterior crural*, in the fold of the groin just outside the femoral artery.

8. The *sciatic*, in the pelvis coats of the rectum, or just below the gluteal fold at the back of the thigh.

9. The *peroneal*, or *external popliteal*, just above the head of the fibula, beside the biceps tendon.

10. The *internal popliteal nerve*, in the popliteal space, and to the inner side of the tendon Achilles.

39. In the face:

11. The *facial*, through the cartilage of the lower surface of the meatus auditorius. Its chief ramifications can be reached where they emerge from the parotid gland. Erb chooses for stimulation three main branches of the facial: (1) for muscles above the palpebral aperture; (2) for those in front of the upper jaw, between the orbit and the mouth; (3) for muscles of the lower jaw. He tests each of these in two places, first at

points just in front of the ears, and secondly for (1) at the temple, for (2) at anterior extremity of zygomatic bone near its lower border, for (3) at the middle of the inferior border of the horizontal ramus of the lower jaw.

12. The *fifth*, at the supraorbital foramen, at the infraorbital foramen, at the foramen mentale, on the side of the tongue.

40. In the neck:

13. The *spinal accessory*, at the top of the supraclavicular triangle, where the nerve pierces the sternomastoid.

14. The *phrenic*, on the outer edge of the lower part of the sternomastoid.

15. The *hypoglossal*, along the upper border of the great cornu of the hyoid bone.

16. The *recurrent laryngeal*, along the outer border of the trachea.

17. The *pneumogastric* and *glossopharyngeal*, along the track of the carotid artery just below the angle of the jaw.

41. Frequently it happens that paralysis affects a group of muscles. It is then necessary in making a diagnosis to trace back the nerve-supply of the affected muscles to their spinal roots. Muscles physiologically related may receive their nerve-supply from different motor roots. The following table, by Dr. Ferrier, gives the more important spinal nerve-roots, with the muscles supplied by each.

42. Nerve-roots:

4th Cervical.—Deltoid, rhomboids, spinati, biceps; brachialis anticus, supinator longus; extensors of the hand.

5th Cervical.—Deltoid (clavicular portion), biceps, brachialis anticus, serratus magnus, supinator longus; extensors of the hand.

6th Cervical.—Latissimus dorsi, pectoralis major, serratus magnus, pronators, triceps.

7th Cervical.—Teres minor, latissimus dorsi, subscapularis, pectoralis minor, flexors of the hand, triceps.

8th Cervical.—Flexors of wrist and fingers, muscles of hand, extensors of wrist and fingers, triceps.

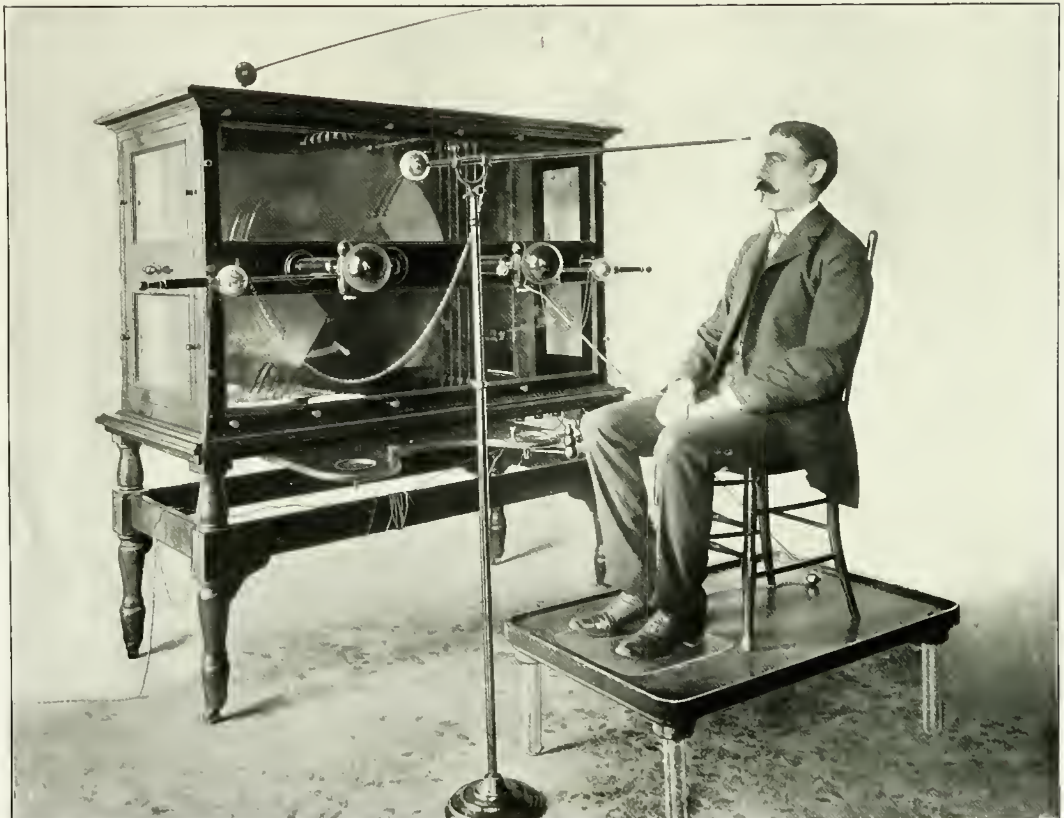

PLATE XI.

Stationary Breeze to Forehead.

43. *1st Dorsal.*—Muscles of hand: thenar, hypothenar, interossei.

3d Lumbar.—Iliopsoas, sartorius, adductors, extensor cruris.

4th Lumbar.—Extensor femoris et cruris, peroneus longus, adductors.

5th Lumbar.—Flexors and extensors of toes, tibial, sural, and peroneal muscles, extensors and rotators of thigh, hamstrings.

1st Sacral.—Calf, hamstrings, long flexor of great toe, intrinsic muscles of foot.

44. Dr. Heringham gives the following table from the dissections of the brachial plexus of infants:

Usual nerve-supply:

3d, 4th, and 5th Cervical.—Levator anguli scapulæ.

5th Cervical.—Rhomboids.

5th, or 5th and 6th Cervical.—Supraspinatus, infraspinatus, teres minor.

5th and 6th Cervical.—Subscapularis, deltoid, biceps, brachialis anticus.

6th Cervical.—Teres major, pronator radii teres, flexor carpi radialis. Supinator longus and brevis. Superficial thenar muscles.

5th, 6th, and 7th Cervical.—Serratus magnus.

6th or 7th Cervical.—Extensores carpi radialis.

7th Cervical.—Coracobrachialis, latissimus dorsi, extensor at back of forearm, outer head of triceps.

7th and 8th Cervical.—Inner head of triceps.

7th, 8th, and 1st Dorsal.—Flexor sublimus and profundus, flexor carpi ulnaris, flexor longus pollicis, and pronator quadratus.

8th Cervical.—Long head of triceps, hypothenar muscles, interossei, deep thenar muscles.

The pectoralis major from the 6th, 7th, 8th, and 1st dorsal.

The pectoralis minor from the 7th, 8th, and 1st dorsal.

45. The Dispersing Electrode.—In investigating the electrical reactions of nerve and muscle the surface area of the active electrode should be small, so that it can be adapted to all surfaces. About $\frac{1}{3}$ inch in diameter is the size usually

employed. The inactive or dispersing electrode should be much larger, to diminish current-density, and to prevent the local electrolytic action of the current. The size and position of the dispersing electrode are right when they annoy neither the patient nor the physician. For the usual electrical tests, the dispersing electrode should have a surface area of about 12 square inches. It should be made of block-tin or thoroughly annealed copper, and covered with felt or amidou. The patient can easily hold the dispersing electrode in position, leaving the physician to manipulate the active electrode and the part of the body under examination.

46. Electrical diagnosis of nerves and muscles presupposes on the part of the investigator thorough knowledge of the topographical anatomy of the human body, and a more than ordinary familiarity with the technique of electrical appliances. Attention to details and repeated exercises in locating motor points, both on one's self and on patients, are necessary to acquire proficiency in electrical diagonsis.

The manner in which the muscles contract, the different muscles that respond when an electrical stimulus is applied to a nerve, the number of milliamperes required to produce contraction, the resistance of the skin, and the location of the nerve, whether deep or superficial, are all matters that should be closely observed.

47. As *RD* (*RD* being an abbreviation for reaction of degeneration) follows disease or injury of the nuclei of origin for the cranial nerves or of the ganglion-cells of the anterior cornua or of the motor nerve-trunks, the importance of disclosing its existence must be apparent. The time required for each examination (which practice considerably shortens) is fully compensated for by a knowledge of the trophic condition of the lower motor segment more definite and satisfactory than can be acquired by any other method of examination. *RD* excludes at once the brain, the white matter of the cord, hysterical paralysis, shamming, idiopathic muscular atrophy, and clears the ground in a very appreciable manner for the consideration of other diseases of the cerebrospinal axis.

The tendency to neglect the electrical investigation of nerve and muscle is not easily explained, since the investigation gives definite results that enable the physician to form a prognosis and to institute rational treatment. When muscles and motor nerves are under investigation, the direct current is an indispensable aid.

CONSTANT CURRENTS.

48. Properties.—The properties of the direct, or galvanic, current are (1) physical, (2) physiological, (3) chemical.

The physical properties are (1) light, (2) heat, (3) magnetism.

The physiological properties are (1) contraction of protoplasm, (2) increased or decreased sensibility.

The chemical properties are (1) electrolysis, (2) cataphoresis, (3) catalysis.

In practice, or even theoretically, it is difficult to separate electrolysis from cataphoresis.

Light, as a property of the galvanic current, will be considered in an article on the illumination of the cavities of the body; and heat, in an article on galvanocauterization.

MAGNETISM.

49. Wherever there is an electric current there is a magnetic field—steady, if the current is steady; alternating, if the current is alternating. It is the influence of these magnetic fields on the tissue metabolism of the human organism that shall be considered here. If the properties of a molecule depend on the arrangement of the atoms that compose it as much as they do on the kind of matter, it would be strange if lines of magnetic stress had no influence whatever on the rate of change in life processes. Only a few years ago magnetic fields were believed to have no influence on the human organism. In a paper read before the American Electrotherapeutic Association, in 1892, Dr. Peterson and Mr. Kennelly reported the results of their experiments on this subject. The authors of this paper gave their conclusions from various experiments, carefully conducted, in the following statement:

"The human organism is in no wise apparently affected by the most powerful magnets known to modern science; neither direct nor reversed magnetism exerts any perceptible influence upon the iron contained in the blood, upon the circulation, upon ciliary or protoplasmic movements, upon sensory or motor nerves, or upon the brain."

It had long been believed by many that magnetism had an important place among those agencies that control the nutrition of the human body, both in health and in disease. The conclusions in the above statement from Dr. Peterson and Mr. Kennelly were, however, accepted by investigators, because nothing to the contrary had been experimentally demonstrated.

50. Experiments by Peterson and Kennelly.—The first series of observations were made on a drop of water, pulverized iron, powdered hemoglobin, living ciliated epithelium, and the circulation of the blood in a frog-foot preparation. These were placed in the field of a microscope, and inserted between the poles of a powerful electromagnet. The drop of water and the pulverized iron were influenced by the magnetic field, but the hemoglobin, the ciliated epithelium, and the circulation of the blood were in no wise disturbed.

In the second series of experiments, the influence of stress-lines on the conductivity of a motor nerve was studied. For this purpose, a small dog was enclosed for some hours in a strong magnetic field. The result was negative.

The third and fourth series were the most important, as they were conducted with a view of determining the action of steady and alternating magnetic fields on the physiology of the human organism. The subject placed his head between the poles of a powerful electromagnet, which could be excited from a dynamo machine. They reported as follows: "Five men, ourselves among the number, were subjected to trial. One case described will describe all. The subject lay back upon the board and concentrated his attention upon his sensations. His right wrist was extended and was grasped by one observer, who took sphygmographic tracings of the pulse. A second observer placed a hand on his chest, to observe any irregularities that

might occur in respiration. A third observer, in view of these two, but unseen by the subject of the experiment, opened and closed the switch that excited and released the field, signaling to the first two observers as he did so. The strong magnetic influence was therefore turned on or off at will, and without the knowledge of the subject. Several sphygmographic tracings were taken in each of our subjects, and in one the knee-jerk was tested continuously. The sphygmographic tracings taken during the *séance* show no change in regularity, in spite of making and breaking of the enormous magnetic influence during its registration. The respirations were not changed in the least. The knee-jerk also presented absolutely no change. As to common sensations, there were none that could be attributed to the magnetic influence, and the subject could not discover when or whether the field had been excited. The testimony of all five subjects was alike."

The fourth, and final, series was made to test the effect of an alternating magnetic field. The magnetism was reversed 280 times a second. The alternating electromotive force was 1,200 volts, the current supplied being 1.85 amperes.

"Each of the authors acted as subjects in the experiments, permitting the 1,200-volt alternating current to be made and broken frequently in the huge magnetic coil surrounding his head. No effect whatever was experienced. The coil itself hummed with the current, and a strip of sheet iron held in the cavity of the coil, but not touching it, vibrated perceptibly in the hand and gave a distinct, loud sound, which was determined to be middle C of a musical scale."

Dr. Peterson and Mr. Kennelly restricted themselves to a study of the pulse, of the respiration, of the knee-jerk, and of the subjective sensations of the individual in the magnetic field. Physiological chemistry is not mentioned, and received from them no attention whatever. The chemistry of the excretions gives the most reliable data for conclusions on tissue metabolism. The value of chemical analysis of the excretions is very clearly demonstrated in the investigations of Professor Bouchard on diseases characterized by slowness of nutritive processes.

If the methods pursued by Bouchard had been adopted by Dr. Peterson and Mr. Kennelly, these authors would have been able to report very different results. The pulse, temperature, respirations, knee-jerk, and subjective sensations should of course receive careful study, but it is only by attention to all the details of "control-experiments," and by a rigorous application of the physiological chemistry of digestion, assimilation, and excretion, that reliable data can be obtained concerning the influence of magnetic stress on life processes.

Our knowledge of the influence of magnetic stress on animal functions, in 1892, may be found in the statement from Dr. Peterson and Mr. Kennelly quoted in Art. **49.** Indeed, it was then universally believed that any action on the human body attributed to magnetic fields was wholly psychic. It was about this time that Professor Herdman, of the University of Michigan, began his series of elaborate experiments to determine the influence of alternating magnetic fields upon the metabolic processes of the human organism, and upon the growth and development of animals.

51. Experiment by Prof. W. J. Herdman.—To investigate the influence of alternating magnet fields upon man and animals, Professor Herdman caused to be constructed, in the laboratory of the University of Michigan, a solenoid 3 feet in diameter, of No. 10 Underwriters' wire, and with a sufficient number of turns so that a current-strength of 5 amperes produced an average of 65 C. G. S. lines for each square inch of space in a plane cross-secting the space within the coil. The current employed to excite the solenoid was obtained from a Thomson-Houston alternating dynamo. This dynamo makes 248 alternations a second.

52. First Series of Experiments.—In this first series of experiments the influence of the alternating magnetic field was determined by the output of urea. Three subjects were chosen. Two were healthy young men, students of medicine, and the other was a man 38 years of age suffering from paralysis agitans. He was otherwise in good health. For 1 week before being submitted to the magnetic action, all three

subjects were dieted, and the daily output of urea carefully estimated. During the next week, each man was placed comfortably within the solenoid for 2 hours each day. The diet, mode of living, and all other conditions were the same as the first week, with the exception of the alternating field. A careful daily estimate of the urea was made. All the details of control-experiments were rigorously observed.

53. Effects Produced.—There was no change in respiration, temperature, pulse, or arterial tension. The subject suffering with paralysis agitans claimed a soothing, sedative effect from the magnetic action, and this effect lasted for some hours after he left the solenoid. In all three cases there was an increase of 10 per cent. in the urea eliminated during the second week over that eliminated during the first week. These three experiments show, then, a marked difference in the amount of urea eliminated during two consecutive weeks. As all the conditions were alike during both weeks, except the alternating magnetic field, the increased elimination of urea may be attributed to the magnetic action.

54. Second Series.—The second series of experiments was instituted to determine the effects of alternating magnetic fields in retarding or accelerating the growth of young animals. These experiments were made on rabbits and guinea pigs. Two groups of guinea pigs and rabbits were chosen as nearly alike in age and weight as possible. The conditions of living and surroundings for each group were similar, except that from 6 o'clock in the evening until midnight one group was placed in a solenoid actuated by a 5-ampere alternating current, and the other group was placed in a similar solenoid not actuated by any current. Each group of animals was treated in this manner until they had reached their full growth.

Professor Herdman has been experimenting in this manner since 1893, or one year after the communication of Dr. Peterson and Mr. Kennelly to the American Electrotherapeutic Association. His control-experiments during these years have been many, and he concludes from his investigations that magnetic energy is in some way transformed into physiological energy,

and this increased physiological energy manifests itself in the increased weight, increased growth and development of the animals experimented on, and in the increased elimination of urea in man. From these experiments on animals and man, one cannot escape the conclusion that alternating magnetic fields and quickened tissue metabolism stand in the relation of cause and effect.

Professor Herdman is still engaged in this line of investigations, in order to satisfy himself and all others who may be interested in the subject as to the genuineness of this relationship of vital activity of animal organism to magnetism. In his recent experiments, the time during which the animals were submitted to magnetic action was lengthened from 7 hours to 12 or 14 hours each day. After a few days, the animals submitted to this magnetic influence showed signs of exhaustion. They became inactive, and sat huddled together in one side of the solenoid. The control animals in the adjoining solenoid were active and lively. At the end of 4 weeks, some of the animals died; and at the end of 5 weeks, all of them had succumbed.

These recent experiments teach that the time during which the animals were placed daily in the active solenoid was too long. Overstimulation was produced, and the animals died of exhaustion. It was of course to be expected that if a few hours daily in an active solenoid quickened tissue metabolism 20 or 30 per cent., 12 or 14 hours, daily, in the same active solenoid must exhaust rapidly the resources of the tissues and produce death. From these experiments, conceived and carried out by Professor Herdman, a rational method of treatment for diseases characterized by suboxidation or retarded metabolism should follow.

ELECTROLYSIS.

55. Nature of Electrolysis.—Electrolysis is the separation into its component parts of a compound body in solution, by an electric current. Electrolysis may be simple or complex; simple, when the electrolyte is composed of only two elements, and complex when composed of more than two elements. The

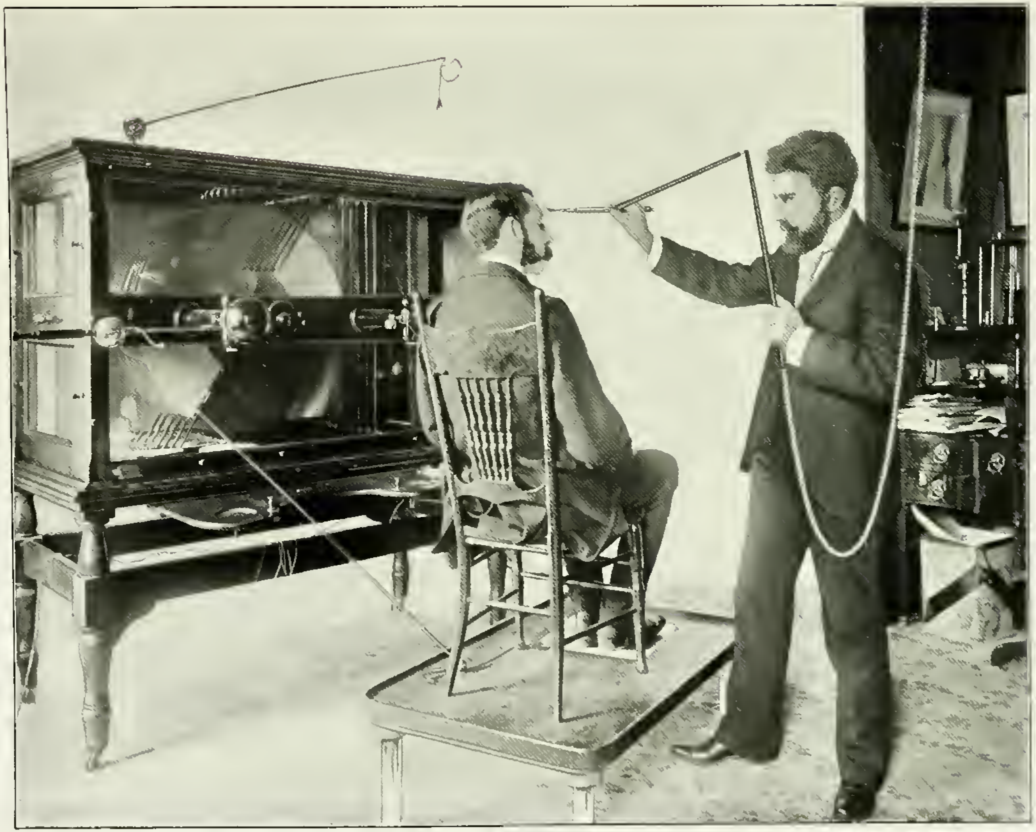

PLATE XII.

Movable Negative Spray to Forehead.

decomposed elements are called *ions*. Those ions collecting at the positive pole are called *anions;* those collecting at the negative pole are called *cations*. An ion may be a single atom of an element or a molecule acting as a radical. In a vessel containing water, place two platinum electrodes connected with the binding-posts of a galvanic battery, and turn on the current. The current entering the water at the positive pole supplies the analytic energy to decompose the molecules of water into their chemical equivalents. Elements unite to form compounds in the proportion of their chemical equivalents; they are decomposed in the same proportion. Two atoms of hydrogen and 1 atom of oxygen are formed. The oxygen, being electro-negative, appears at the positive pole, and is liberated there. The 2 atoms of hydrogen in their nascent state combine with the oxygen of the next molecule of water, again liberating 2 atoms of hydrogen. This process of decomposition and recombination continues across the interpolar field until there is no more oxygen remaining with which the hydrogen could combine, and it is liberated at the negative pole. This is *primary* electrolysis, and its theory was given by Groothuss in the year 1805.

An electrolyte is a compound substance that conducts electricity by virtue of chemical decomposition. It may be either liquid or semisolid. When the decomposed ions unite with the elements of the electrolyte or with the electrodes, the process is known as *secondary* electrolysis.

56. Electrolysis Distinguished From Galvanocauterization.—Galvanocauterization and electrolysis must not be confounded. In galvanocauterization, use is made of a large quantity of electricity passing through a substance of high resistance, as a platinum loop. The platinum loop, by the transformation of electric energy into heat energy, becomes heated, and it is the heat and not electricity that is utilized in galvanocauterization. The tissues, by the action of galvanocauterization, are destroyed *en masse*, without any regard to their chemical composition. In electrolyzing animal tissues, heat is not an element to be considered. There is no more heat than

can be accounted for by the activity of the chemical processes going on. The chemical activity in a galvanic cell depends on the strength of the current. In the same manner, the amount and activity of electrolysis in any tissue depends on the current-strength sent through the tissues, and the length of time the current is passing. When electrolysis alone is desired, the electrodes must be composed of some material not acted on by the galvanic current. In this case, the positive pole should be made of some non-oxidizable material, as platinum, carbon, or gold. The negative pole is not acted on by the galvanic current; its composition is therefore a matter of indifference.

57. Amount of Chemical Action Equal in All Parts of a Circuit.—If several separate compartments containing water are connected with the binding-posts of a galvanic battery, and a current passed through them, the amount of hydrogen collected at the cathode of each compartment will be equal. The same is true for oxygen at each anode. These compartments are known as *electrolytic cells*. Pour a solution of cupric sulfate into each compartment, instead of water, and pass a current through them; the amount of copper deposited at each cathode will be found to be the same. Any electrolytic solution may be treated in the same manner.

The amount of any ion liberated in any given time is proportional to the strength of the current and to the chemical equivalent of the ion.

58. Chemical Decomposition.—Every electrolyte, during the passage of an electric current, undergoes chemical decomposition. No matter how weak the galvanic current passing through an electrolyte may be, its passage represents more or less decomposition. It is very important to always remember this in applying galvanism to the human organism. The electrolysis of the various saline and acid solutions have been carefully studied in laboratory experiments. What takes place in the electrolysis of animal tissues is best studied in the results produced by passing a current through a piece of butcher's beef. Knowing the facility with which saline solutions are electrolyzed in laboratory experiments, it will be easily

understood how chemical decomposition can take place in substances so largely composed of water and saline materials, as muscles, nerves, and blood.

59. Electrolysis of Animal Tissue.—Insert two platinum electrodes about $\frac{1}{2}$ inch deep and 4 inches apart into a piece of butcher's beef. This represents nearly enough human muscle. Connect the platinum electrodes with the binding-posts of a galvanic battery, and allow 20 milliamperes to pass for 5 minutes. At the end of 5 minutes, the effect produced at each pole will be very different in character. Beginning observations where the current enters the beef at the positive pole, it will be noticed that it is difficult to withdraw the positive electrode. The tissues have become adherent to it. The surface around the anode is somewhat depressed, and has a glazed, dried appearance. This glazed, dried appearance is due partly to the cataphoric action of the current in driving the liquids from the vicinity of the positive pole, and partly to the action of the acids, muriatic, nitric, sulfuric, and phosphoric, collected at the anode.

60. Changes About the Anode.—The tissues around the anode are also found to be firmer and harder, due to the caustic action of the liberated acids. The principal acid is muriatic, on account of its predominance in animal tissues. The edges of the beef around the anode are inverted. The reaction is acid. The beef around the cathode presents a moist, swollen appearance, with the margins retracted. The electrode is very loose, and is surrounded by a frothy liquid, alkaline in reaction. The swelling is due to the cataphoric action of the current, the liquids of the beef together with the alkalis being attracted by the current to the negative pole. The hydrogen gas liberated at the cathode mechanically separates the fibers of the beef, and contributes to the swelling of the tissues around the cathode. The alkalis at the cathode are soda, potash, lime, and ammonia. The eschar produced by the anode is white, firm, hard, small, and non-retractile. The anode is also antiseptic, owing chiefly to the liberated oxygen and chlorin.

With a current-strength of 100 milliamperes, the anode is antiseptic. Its antiseptic property is due to the action of the oxygen and chlorin liberated around it. The eschar produced by the cathode is large, soft, and retractile. The electrolytic action of the current depends on its density in the tissue. The density of the current is in direct proportion to the current-strength, and in inverse proportion to the surface area of the electrode. The visible action of the current extends farther around the cathode than around the anode.

61. The Interpolar Region.—In the interpolar region, to the naked eye there is no change. Between the poles, the piece of beef seems the same after the current has passed as it did before. What the electrolytic interpolar changes are, has not yet been satisfactorily demonstrated. There are several reasons for believing that chemical decomposition and recombination do take place in the interpolar area. According to Dr. Stewart, all conduction in animal tissues is electrolytic, and the electrolytes are chiefly the inorganic constituents. When a current of moderate strength has passed through the human body for a few minutes, if the rheophores are taken from the battery and attached to a galvanometer, a current will pass through the rheophores to the galvanometer. This demonstrates polarization in the interpolar area, and polarization could not take place without chemical action. Hold the electrodes of a galvanic battery in the hands, and let a moderate current flow through the body for a few minutes. Let go of the electrodes, and place the hands in two vessels containing salt water connected with a galvanometer. The needle will at once be deflected, demonstrating the passage of a current. Microscopical examination of the interpolar tissues has also demonstrated marked changes even after the passage of comparatively weak currents. It is very probable, however, that most of the ions, the product of interpolar electrolysis, are swept along by the cataphoric action of the current, and are found at the cathode.

62. With currents passing in the same direction, M. Weiss points out that the strength of the contraction continually

decreases. If, however, the current is reversed, the contraction immediately gains in strength. This observation is to be explained only on the polarization of the current, and polarization could not take place without chemical decomposition. If the muscles had been fatigued by passing the current in one direction, rest would have been restored; but rest, he found, did not do it. The reversal of the current restored the contractions to their original vigor, and this meant destroying the polarization and restoring normal chemical composition.

63. Action of the Anode.—The physiological and chemical properties of both poles of the galvanic current have now been described. A brief summary of their action is as follows: The anode is sedative, since it diminishes the irritability of tissues; anticongestive, for it drives liquids and solids towards the cathode. It is an acid caustic, producing mummifying effects; the eschar is dry, hard, and non-retractile; through the oxygen and chlorin that it liberates, it is antiseptic.

64. Action of the Cathode.—The cathode is a stimulant, since it increases the irritability of tissues. It is congestive, producing an accumulation of liquids and salts; with mild currents, it promotes nutrition; with strong currents, it has denutritive effects. It produces an accumulation of hydrogen and the caustic hydrate of sodium, potassium, and ammonium. These form saponaceous matter, and are caustic alkalis. The effect of both poles is (1) to produce anemia, (2) to produce hyperemia, and (3) to produce equalization of the circulation. The cathode has no antiseptic action, nor does it act on the electrode used. The anode has antiseptic properties, and attacks the electrode used if it is soluble or oxidizable. By catalysis is generally understood the interpolar effects of the galvanic current. It includes interpolar, electrolytic, and cataphoric effects; also, the effects on the vasomotor nerves, and the circulation of blood and lymph in the tissues of the body. The flow of blood and lymph is increased in the interpolar region by the galvanic current. As a consequence, the absorbing capacity of the tissues is increased and the trophic condition improved. It is convenient to retain the word

catalysis, meaning by it the changes produced in the interpolar region by the galvanic current. These changes are absorbent, alterative, and nutritive.

65. Polar Properties of Galvanic Current.—The polar properties of the galvanic current may be tabulated as follows:

NEGATIVE	Physiological Stimulant	Catelectrotonus. Increased irritability of negative pole.
	Chemical	Accumulation of hydrogen and alkalis, hydrate of calcium, potassium, sodium, and ammonium. These form saponaceous matter, and are caustic alkalis. Eschar is large, soft, and retractile.
	Cataphoric	Accumulation of liquids and salts. With mild currents promotes nutrition. With strong currents destroys tissues and has denutritive effects. First effect is to cause ischemia; second, hyperemia, and then an equalization of the circulation.
POSITIVE	Physiological Sedative	Anelectrotonus. Diminished irritability of the positive pole.
	Chemical	Accumulation of oxygen, chlorin, nitric, phosphoric, sulfuric, and muriatic acids. It is an acid caustic, producing mummifying effects. The eschar is small, dry, hard, and non-tractile.
	Cataphoric Antiseptic	Loss of fluids and salts. Starvation of tissues. Diffusion of drugs in solution, or nascent salts formed by electrolysis of soluble metallic electrodes.

66. Mechanical Action of Hydrogen.—There are three chief factors in the electrolysis of tissues in living animals, namely: (*a*) the physical or mechanical, (*b*) the chemical, and (*c*) the physiological or therapeutic. The physiological factor

produces alterations in the nutrition of tissues through which the direct current passes. The chemical factor has already been described. The chemical factor in electrolysis must necessarily precede the physical factor, and bears to it the relation of cause and effect. This physical factor, or the action of hydrogen in separating the tissues around the negative electrode, is too often forgotten. Hydrogen is the most diffusible of all gases; it leaks rapidly through stop-cocks that are oxygen- or nitrogen-proof. In the dilation of strictured canals, hydrogen is an important factor. The disintegrating action of hydrogen on the tissues does not cause their destruction. By its mechanical action, it reduces the resistance of tissues so that an instrument may more readily pass through them.

As electrolysis proceeds, hydrogen gas is constantly accumulating, and if the dilating electrode occludes the orifice of the stricture, the hydrogen will have the tendency to dilate the stricture by forcing its passage through it. It has been calculated that for every cubic centimeter of hydrogen liberated in electrolysis of stricture, $\frac{1}{18}$ grain of mixed caustic alkalis is produced. This caustic is gradually spread over the mucous surface of the canal. During one séance not more than $\frac{1}{2}$ cubic centimeter of hydrogen is liberated, and the quantity of caustics must be diminished in like ratio. In manipulating electrodes during the treatment of any strictured canal, this property of hydrogen to separate and relax the tissues should be always remembered.

CATAPHORESIS.

67. The introduction of medicaments into the body per-mucous or percutaneous, by means of electricity, is called *cataphoresis.* It is a physical process. The medicament is forced through the skin or mucous membrane by the current, and is conveyed along the lines of the current to a greater or less depth into the tissues. Various drugs in solution may in this way be introduced into the body where they exert their specific influence. Solid substances may also be dissolved by the anodal action and diffused into the tissues.

ELECTRICAL OSMOSIS.

68. When two fluids of different densities are separated by a porous membrane, currents of unequal strength flow between them. The stronger current is from the fluid of less density to that of greater density, so that in time there will be established a difference in level between the two fluids. When this difference in level is produced, the pressure exerted by the higher level will gradually lessen the stronger current from the fluid of less density and restore the two fluids to their original level.

This difference between fluids of different densities separated by an animal membrane may be influenced by passing through them a current of electricity. If a platinum electrode is inserted into each compartment, containing fluids of different densities and separated by a porous membrane, the stronger current will, on making the circuit, always be from the positive to the negative pole, from the fluid of less density to that of greater density, or the reverse, according to the position of the poles.

69. The human body may be regarded as made up of tissues or septa bathed in acid or saline solutions. By means of the electric current, these fluids, with the solids they hold in solution, may be moved from one part of the body to another. This has been named by Dubois-Raymond "the cataphoric action of the galvanic current." If, through a piece of muscle removed from the body, a current of electricity is passed, the negative end will become swollen from the accumulation of fluids and solids there, and the positive end will become dry and mummified, due to the accumulation of acids and the absence of liquids.

70. That the electric current can carry with it solid bodies, as well as substances held in solution, the following experiment proves. Into a **U**-shaped glass tube, Fig. 24, nearly filled with water slightly acidulated with sulfuric acid, place a globule of mercury. Into the acidulated water at each end of the tube insert the platinum electrodes of a galvanic battery. On making the circuit, the globule of mercury will be observed to move in

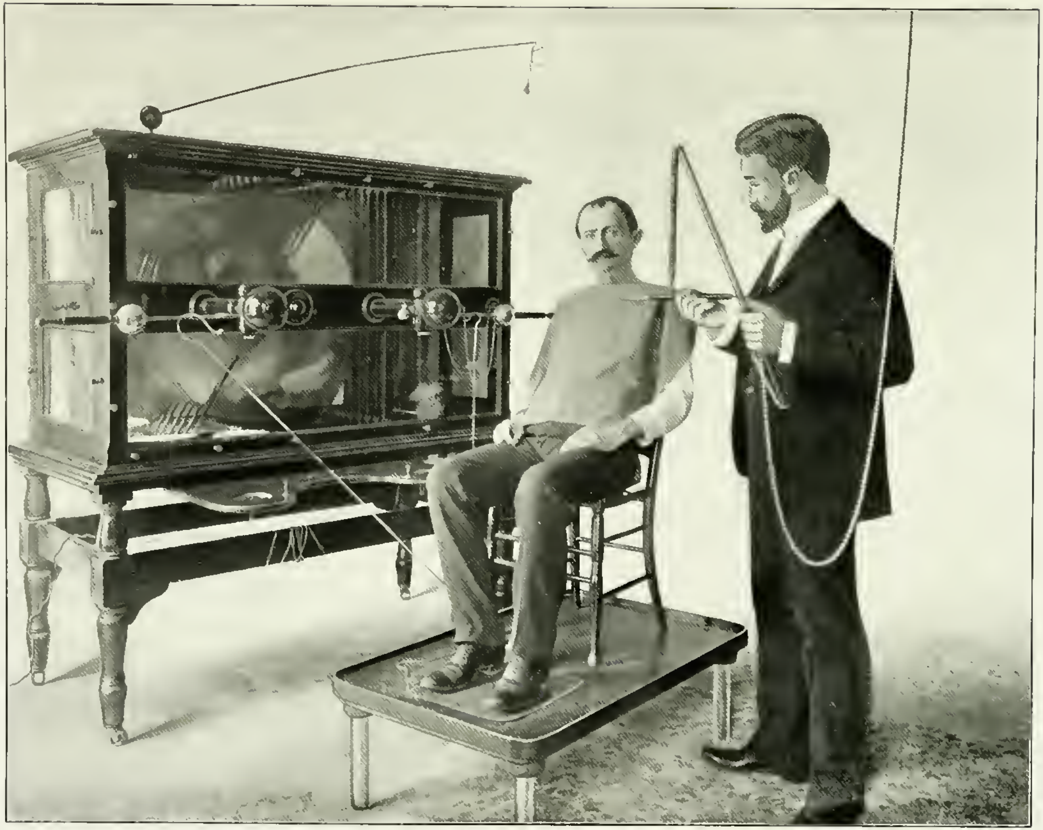

PLATE XIII.

the direction from anode to cathode. Suddenly reverse the current and the globule of mercury will change its direction. If the **U**-shaped glass tube is supported in an inclined position, the globule of mercury may be forced along it from anode to cathode, against the action of gravity. The globule of mercury may even be steadied in one position during the flow of current, and sustained there by the opposing forces of the current-strength and gravitation. Solid particles of graphite have in this way been drawn into the skin. Simple medicinal cataphoresis, for its systemic effects, has not been much employed. The amount of cataphoresis obtained depends on the electric resistance of the fluids used. Substances of very high electric resistance, like chloroform, ether, alchohol, and glycerin, allow

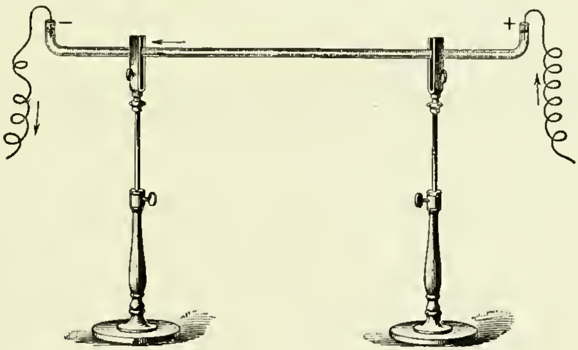

FIG. 24.

a very small amount of current to pass, and very little cataphoresis takes place. In solutions strongly acid or strongly alkaline, the electric resistance is low. They permit a large quantity of current to pass, with but little or no cataphoric action.

GALVANOCOCAIN ANESTHESIA.

71. Method of Application.—Neither the electric current nor cocain separately applied to the skin produces complete anesthesia, but a solution of cocain used upon the positive pole will produce a decided anesthetic local effect. A 15- or 20-per-cent. solution of cocain in water may be used in

the following manner: Fill the reservoir of the block-tin electrode shown in Fig. 25 with the cocain solution. Cover the perforator in the electrode with a piece of blotting-paper, also saturated with the solution, and apply the electrode to the skin. Make the electrode positive, and turn on, through the rheostat, a current of from 5 to 10 milliamperes for 10 minutes. With an 8-per-cent. aqueous solution, at least 10 minutes will be required to produce local anesthesia. The negative pole is held in the hand of the patient. Aqueous solutions of cocain have been used with very good results, for the relief and cure of very obstinate forms of neuralgia. Cocain used in this way will find many applications in routine practice. It does not, however, when dissolved in water, produce sufficient anesthesia for the performance of minor surgical operations.

FIG. 25.
DR. W. J. MORTON'S ELECTRODE.

Before applying the electrode armed with aqueous solutions, the skin should be first freed from its fats by thorough washing with soap and water.

72. Guaiacol Solutions.—Galvanococain anesthesia produced with an 8-per-cent. solution of cocain in guaiacol is profound, and has very much facilitated all the operations of minor surgery. Galvanococain anesthesia with the 8-per-cent. guaiacol solution is produced in the following manner: In using the guaiacol-cocain solution, no preparation of the skin is necessary. The reservoir of the block-tin electrode is first filled with the solution, and the perforations covered with a circular piece of blotting-paper saturated with the solution. The electrode is made positive, and applied gently but firmly to the part to be anesthetized. The negative electrode is held in the patient's hand. Turn on through the rheostat a current of from 1 to 3 milliamperes. This will in 2 or 3 minutes produce profound cocain anesthesia, which will last

for 30 minutes. A rheostat and a milliammeter are necessary in the circuit. If the current is gradually turned on through the rheostat, and after 3 minutes' duration gradually turned off in the same manner, the patient experiences absolutely no pain. Eight per cent. is the strength of the solution generally employed, but it may be used with perfect safety as strong as 30 per cent. Up to the present time there have been no cases reported of constitutional effects ascribed to the use of cocain in this manner. Electrodes of different sizes and shapes are manufactured, adapted to the extent and location of tissues to be anesthetized. The guaiacol seems in some way to localize the action of cocain, and to prevent its diffusion into the general system.

CATAPHORESIS IN DENTISTRY.

73. History.—Doctors McGraw and Westlake did the earliest experimental work in anesthetizing sensitive dentin; but the subject was not taken up by the dental profession, and it fell into disuse. A paper by Dr. W. J. Morton in "The Dental Cosmos" for January, 1896, brought cataphoresis to the attention of dentists; and the methods taught by him are now generally used by dentists for anesthetizing the gums and sensitive dentin. Among other things, Dr. Morton claims (1) that sensitive dentin may, with the greatest ease, be so thoroughly anesthetized that operations on it and in it cause no pain; (2) that the dental pulp, even though not fully exposed, may be anesthetized so that instruments may enter the pulp-cavity without pain; (3) that, by employing a properly constructed electrode, soft tissues like the gums may be completely anesthetized to the pain of cutting and tearing operations.

74. Medicaments and Electrodes.—Special electrodes (active and dispersing) are constructed for cataphoric work in dentistry. As these electrodes are illustrated in the catalogues of manufacturers, they need not be described here. Solutions of cocain may be dissolved in water, or an 8-per-cent. solution in guaiacol may be used. All cocain solutions deteriorate rapidly in anesthetic power, and should therefore be freshly prepared

for each application. For sensitive dentin, solutions varying from 10 to 30 per cent. are used, and for mucous surfaces from 4 to 10 per cent. A guaiacol solution of cocain is now generally used. Dr. W. J. Morton, to whom belongs the use of guaiacol solutions of cocain, claims that "guaiacol restrains the action of cocain to local territory, increases the rate of its cataphoric penetration through the epidermis and other tissues, slows the rate of its absorption into the system, prevents consequent toxic effects, and adds its own anesthetic qualities to those of cocain."

75. Anesthetizing Sensitive Dentin.—The electrode should have a surface area equal to that of the surface to be anesthetized. The polarity of the battery-terminals is tested by placing the terminals in a solution of iodid of potash. The current-strength employed varies from $\frac{1}{10}$ milliampere to 2 milliamperes. As enamel is a non-conductor, the electrode must be placed on some exposed portion of the dentin. Apply the rubber dam to every tooth operated on, and keep the saliva away from the tooth. The current is very gradually turned on, and should it cause any pain, it is immediately reduced. If the circuit is broken while the current is passing, it may produce a disagreeable shock. For this reason, when it becomes necessary to add more of the solution, the current is gradually turned off, the solution added, and the electrode again replaced. The guaiacol-cocain solution requires only one-third the current-strength and one-third the time required by the aqueous solution to render sensitive dentin anesthetic.

The disadvantages of guaiacol are its odor and its softening effect on the rubber dam. The time required to anesthetize sensitive dentin varies from 10 minutes to half an hour.

76. Anesthetizing the Gums.—The electrodes here require attention, as the mistake has been made of applying the positive electrode to one side of the gum and the negative electrode to the other side. This method of application must of course produce anesthesia on one side and hyperesthesia on the other. According to the physiological properties of direct currents, there is always immediately beneath the negative

electrode an area of increased irritability, or catelectrotonus. The positive electrode must therefore be divided, having at each terminal a disk, shaped to adapt itself to the contour of the gum. The negative electrode, made of carbon or block tin and covered with punk, is held in the right hand. The strength of the solution used in anesthetizing the gums varies from 4 to 10 per cent. When the gums and the sensitive dentin are anesthetized, the major part of the dental work may be performed without pain.

77. Sterilization of Dentin.—Electricity, on account of its cataphoric action, is now used to sterilize the teeth; and in teeth thus sterilized, alveolar abscesses are not likely to occur. A hypodermic syringe-electrode, provided with a soluble hollow needle, is introduced into the pulp-cavity whose dentin it is wished to sterilize. The syringe contains a 2-per-cent. solution of sodium chlorid, and a drop or two is injected into the cavity. There is not sufficient oxygen or chlorin in the dentinal tissue to dissolve the metallic electrode, so that it is necessary to inject the solution of sodium chlorid. A weak current is now turned on, and the oxychlorid of the metal formed in the pulp-cavity is electrically diffused. A solid needle may be used as the electrode, if a few drops of the solution of sodium chlorid are first placed in the cavity. If a 4-per-cent. solution of hydrochlorate of cocain is used instead of the sodium solution, this procedure will be much more agreeable to the patient.

78. Bleaching by Cataphoresis.—Peroxid of hydrogen applied topically to the teeth causes them to whiten. The process, however, is slow and superficial. By forcing the bleaching agent into the dentinal tissue by the cataphoric quality of the direct current, the bleaching is more rapid and more enduring. A watery solution of the peroxid of hydrogen is the best preparation for bleaching the teeth. In order to bleach a tooth cataphorically, it is necessary to bring the agent H_2O_2 in contact with a conducting substance. Enamel is a non-conductor, and must be perforated before the tooth can be bleached.

79. Method of Procedure.—Prepare a 25-per-cent. aqueous solution of H_2O_2 to which a little phosphate of soda is added to make a good conductor. This solution is applied by the positive electrode to the tooth that it is desired to bleach. A current-strength of ½ to 1 milliampere is usually sufficient to drive H_2O_2 into the dentin of the tooth if the enamel is broken at any part. Dr. W. J. Morton prepares the aqueous solution of pyrozone as follows: Into a glass tube put 2 cubic centimeters of a 25-per-cent. ethereal solution of pyrozone and 1 cubic centimeter of water. Put the tube in an evaporating-dish, in a warm place, and in about 5 minutes the ether will be entirely evaporated, leaving a watery solution of pyrozone. This preparation does not retain its qualities very long, as oxygen escapes.

In selecting a solution to be used cataphorically, its resistance must first be tested. If the resistance of the solution is too high, no current will pass through it; if the resistance is too low, no cataphoresis will take place.

METALLIC ELECTROLYSIS.

SOLUBLE ELECTRODES.

80. Electric Diffusion of Metallic Salts.—The positive pole is the one generally employed for this purpose, but the negative is also sometimes used. The electrode must be composed of the metal whose therapeutic effect is desired. The electrodes used in this manner are made of iron, zinc, copper, or silver. They are made in various sizes and shapes to adapt themselves to the parts to be acted on. Fig. 26 shows electrodes that are used when it is necessary to protect one mucous surface while making an application to another. One half of the bulb is made up of soluble metal, and the other half is made of ebonite or some insulating material. The electric current by tissue electrolysis liberates oxygen, chlorin, hydrochloric, nitric, phosphoric, and sulfuric acids at the positive

pole. From the composition of the human tissues, hydrochloric acid necessarily predominates. Oxygen and hydrochloric acid in the active nascent state attack vigorously the metal of the

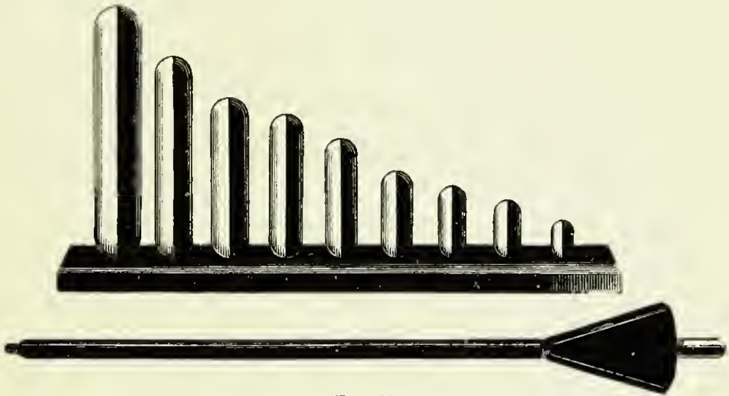

Fig. 26.
Protected Soluble Bulbs.

electrode, and form oxychlorids of the metal used. This double salt of the metals is driven by the current into the tissues, where it produces its known therapeutic action. The amperage of the current used is generally low, varying from 1 to 50 milliamperes. There is very little, if any, tissue electrolysis produced, the current being expended in decomposing

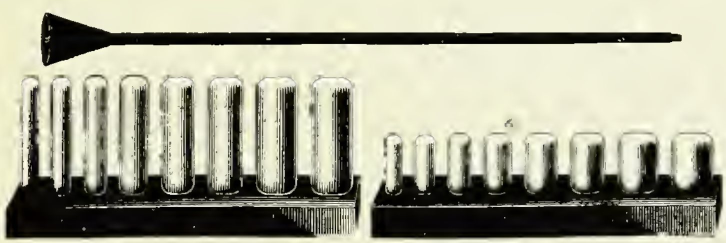

Fig. 27.
Soluble Bulbs

the metal electrode. The advantage of utilizing metallic salts in this manner must be at once apparent. These same salts applied in solution with brush-spray or syringe have their

action restricted almost entirely to the surface, and do not penetrate into the deeper and generally diseased tissues. The electrodes employed in the electric diffusion of metallic salts

FIG. 28.
SOLUBLE NEEDLES.

are in the form of needles or bulbs, as illustrated in Figs. 27, 28, 29, 30, and 31. Metallic electrodes must be kept scrupulously bright and clean, to obtain the best effects.

81. Use of Bulbs.—The bulbs are used in treating diseased mucous tissues, and the needles when it is necessary

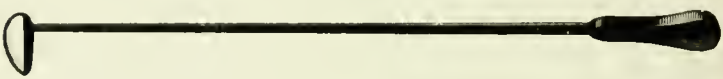

FIG. 29.

to penetrate diseased growths. The needles are 1 millimeter in diameter, and 8 centimeters in length. They will fit an ordinary holder. The bulbs are made in sizes to correspond to the French catheter-scale, and are attached by a screw-thread to a universal holder. These electrodes can be readily adapted to

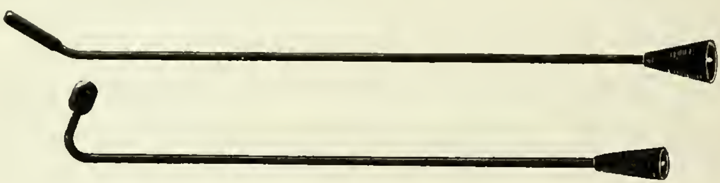

FIG. 30.
SOLUBLE ELECTRODE, POST-NASAL.

any cavity, canal, or surface, as desired. As the positive electrode is the one always employed in electric metallic diffusion, the bulb must always be kept moving, to prevent adhesion and consequent damage to the mucous surfaces. If

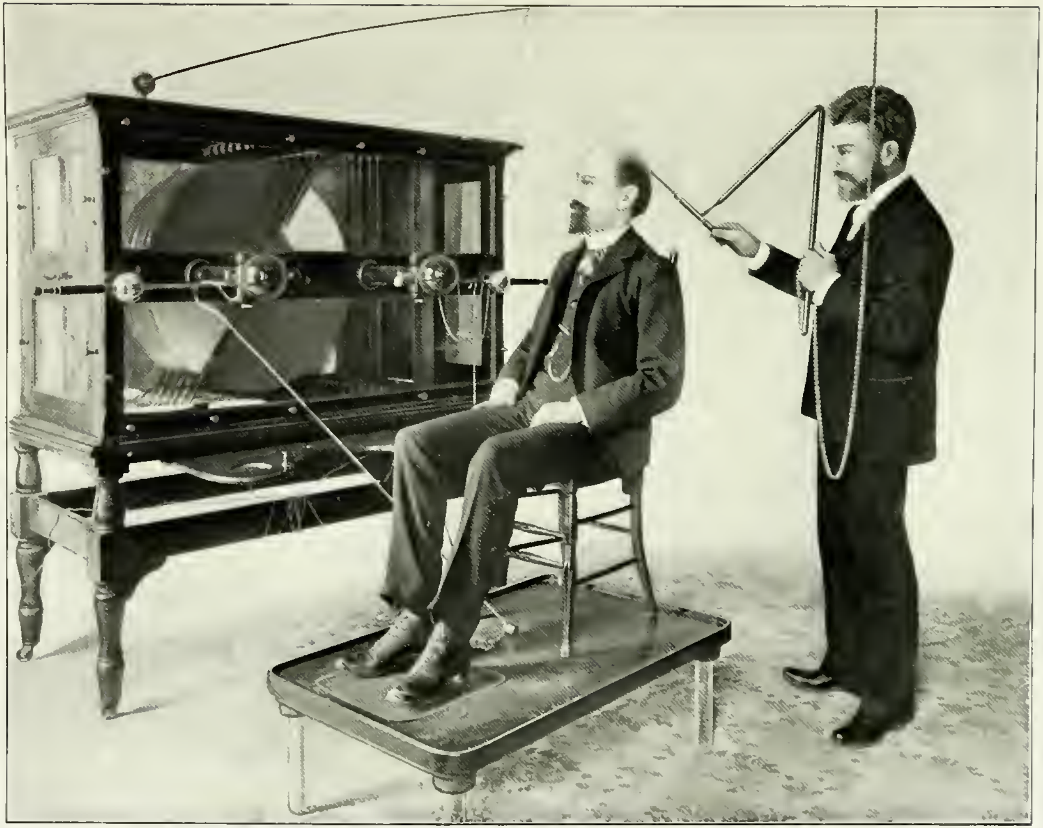

PLATE XIV.

Movable Spray to Occiput.

adhesion should accidentally occur, reverse the polarity; this will free the electrode. The bulbs or needles should always be thoroughly polished with fine emery-paper before being used.

82. Special Electrodes.—The electric current may be utilized in the same manner, to obtain action on deep tissues of various solid medicaments held in solution. Solutions, in varying strength, of cupric sulfate, zinc, chlorid, and other metallic salts may be thus employed to attack the deeper tissues of the nasal cavities, the bladder, and the vagina. For the

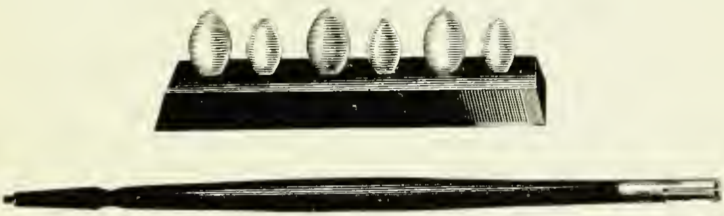

FIG. 31.

treatment of the different mucous cavities of the body, special electrodes are constructed, which may be obtained from the manufacturers. The electrodes used for the nasal cavities, the vagina, and the rectum are shown in the accompanying illustrations. The amperage used for solid medicaments held in solution is low, varying from 1 to 15 or 20 milliamperes, according to the parts treated.

MEDICAMENTAL DIFFUSION.

83. Interstitial Electrolysis.—When writing on the electrical diffusion of cocain into the tissues, cataphoric medication was described. Chloroform, aconite, atropin, and various other drugs are used in the same manner. When writing on the electric diffusion of metallic salts of soluble electrodes, what is known as the *interstitial* electrolysis of Dr. George Gautier was described. A solution of potassium iodid injected into a pathological cavity of the body may be decomposed and diffused into the tissues by the electric current from an insoluble electrode. This is also known as the "interstitial electrolysis of Dr. Gautier."

All these varieties of electromedication have one thing in common, viz., the diffusion of medicine into the tissues by the electric current. Dr. W. J. Morton has united the various processes under the general name of *electric medicamental diffusion*. He points out that, in these various acts, cataphoresis and electrolysis are going on at the same time. The ions are decomposed, reunited, and distributed in obedience to well-known laws, while the principle of cataphoresis, irrespective of ions or chemical changes, moves fluids, with whatever they may contain, in the direction from anode toward cathode.

84. The well-known action of metallic salts locally applied to diseased mucous structures, connected with their diffusion electrically into the deeper parts of the tissues, gives to this mode of treatment the *raison d'etre* of what should be a useful future. It carries with it the manifest advantage that must ever exist between placing a medicament on a morbid surface and diffusing it in a radiating manner into the parenchyma. The salts diffused into the tissues in this manner—into the parenchyma of tissue—do not produce tissue electrolysis. They remain in the tissues as a partly insoluble albumino-metallic salt, exercising by selective affinity a denutritive absorbent action on diseased structures.

85. Experiments on Eggs.—Electric diffusion of metallic salts from soluble electrodes may be very instructively studied in experiments made with bulbs and needles of different composition placed on or inserted in butcher's beef or hard-boiled eggs. Insert both electrodes into the substance of a hard-boiled egg. Connect the electrodes with a galvanic battery. Make the copper electrode positive. Turn on a current of 15 milliamperes for 5 minutes, and observe the effect. Within a radius of about ½ inch around the positive electrode, the substance of the egg will have taken on a green color, due to the diffusion of the copper salt. The same effect will be produced if a copper bulb is held firmly in contact with the egg for the same length of time. If the copper needles are inserted in a piece of butcher's beef, and 15 or 20 milliamperes are allowed to pass during 5 minutes, the green color will be noticed in the

tissues around the anode, whereas there is no discoloration around the cathode. One inch is about the extreme limit of medicamental diffusion that it is possible to obtain in this way. In a general way, it may be stated that currents of low amperage are employed in electromedicamental diffusion. In recent publications, Dr. G. Betton Massey reports cases of sarcoma treated by this method. He used amalgamated zinc electrodes, and attributes his results to the action of the oxychlorids of zinc and mercury on the diseased structures. He also used high current-strength, and the action of the electricity on the diseased cells must have been important in the effects produced.

86. In all electrical applications with bare metallic electrodes, when the action of the current alone is required, the positive pole, if it is the one used, should always be made of some non-oxidizable material. Platinum and carbon are not attacked by the current, and are generally used for the positive pole when metallic electrolysis is not desirable. Gold may also be used, and is not soluble.

87. Electrolysis in Uterine Diseases.—Scarcely a hundred years ago the first known demonstration was given that an electric current would decompose a compound (water) into its component atoms (hydrogen and oxygen). This established electrolysis as a chemical fact. By simple cataphoresis is meant what is generally known as "Porret's Phenomenon," or the transfer of liquids or solids in solution through human tissues or other porous septa by the action of direct currents. The cataphoric action of direct currents in the living animal organism was very forcibly demonstrated by G. N. Stewart, physiologist, in Owens College Physiological Laboratory, Manchester, England. Into the vagina of a living rabbit he passed a hollow metallic electrode. When this metallic electrode was made negative, water was forced through it, whereas none appeared while it was positive. These two properties of direct currents (electrolysis and cataphoresis) must be thoroughly comprehended to intelligently apply metallic electrolysis in uterine diseases.

88. Metallic Electrolysis Applied to Uterine Mucosa.—Prochownick was the first to use a copper electrode as the positive pole in the cervical canal. He applied it first to the cervical canal in a case of gonorrheal infection, using a current-strength of 80 to 100 milliamperes for 10 minutes, and noticed that the gonococci disappeared and the discharge became serous after three applications. To Dr. George Gautier, however, is due the credit of developing and popularizing this method of application, which he designated as a form of interstitial electrolysis. Metallic electrolysis is a more comprehensive term, since the action depends on the electrochemical decomposition of the metal employed as an electrode. This action can take place only at the positive pole, because it is only at the positive pole that direct currents, by decomposing the tissues, liberate oxygen, chlorin, and acids. At the negative pole are found hydrogen, soda, and potassa, which do not attack metals.

Direct currents supply the analytic energy to decompose the tissues (electrolysis). As a result of this decomposition and the chemical structure of tissues, oxygen and chlorin are liberated around the positive pole, and in their nascent state vigorously attack oxidizable electrodes, forming salts of the metals used. Again, the electric current supplies the energy that diffuses these salts into the tissues (cataphoresis).

89. Different Metals Used as Electrodes.—Dr. George Gautier limited his observations to electrodes made of copper, but any other oxidizable electrode may be used, the selection being governed by the effect desired. Doctor Goelet, who was the first in this country to use metallic electrolysis in the interior of the uterus, popularized zinc electrodes. Other writers have used silver, iron, lead, tin, etc. The electrodes are constructed in sizes of the French catheter-scale, and are formed similar to the intra-uterine sound.

90. Advantages of Metallic Electrolysis.—There is no caustic action on the tissues, as is the case when non-attackable electrodes are employed. The current-energy is expended on the electrode and in diffusing the newly formed

salts into the tissues. The uteri of rabbits were submitted by Gautier to the action of cupric electrolysis. The tissues for a considerable distance were stained an apple-green color. He also demonstrated positively that these salts of copper exert no deleterious effect; on the contrary, he found them to be therapeutically valuable. The action of metallic electrolysis can be confined within the desired limits, since the formation of the salt due to the action of the current is limited to the area of contact with the electrode, and is driven from this area into the tissues beneath by cataphoresis.

By regulating the current-strength and the duration of contact of the electrode, the action of the metal can be readily and accurately varied. When slight action only is required, the electrode should be kept in motion and low current-strength employed. Prochownick used 80 to 100 milliamperes in cupric electrolysis, but at the present time 30 milliamperes are rarely exceeded. The caustic action of the current is produced with a current-strength beyond 30 milliamperes. The duration of the application varies from 5 to 15 minutes. The action of the current on the metal takes place quickly, and when iron or copper is employed the electrode becomes adherent to the tissues. If the electrode should become adherent, it can usually be successfully detached by carefully rotating it on its axis before attempting to withdraw it. If necessary, reduce current-strength to zero and use negative polarity for about 4 minutes. The negative action will detach the adherent electrode.

Physiology of Alternating Currents and Hydro-Electric Methods.

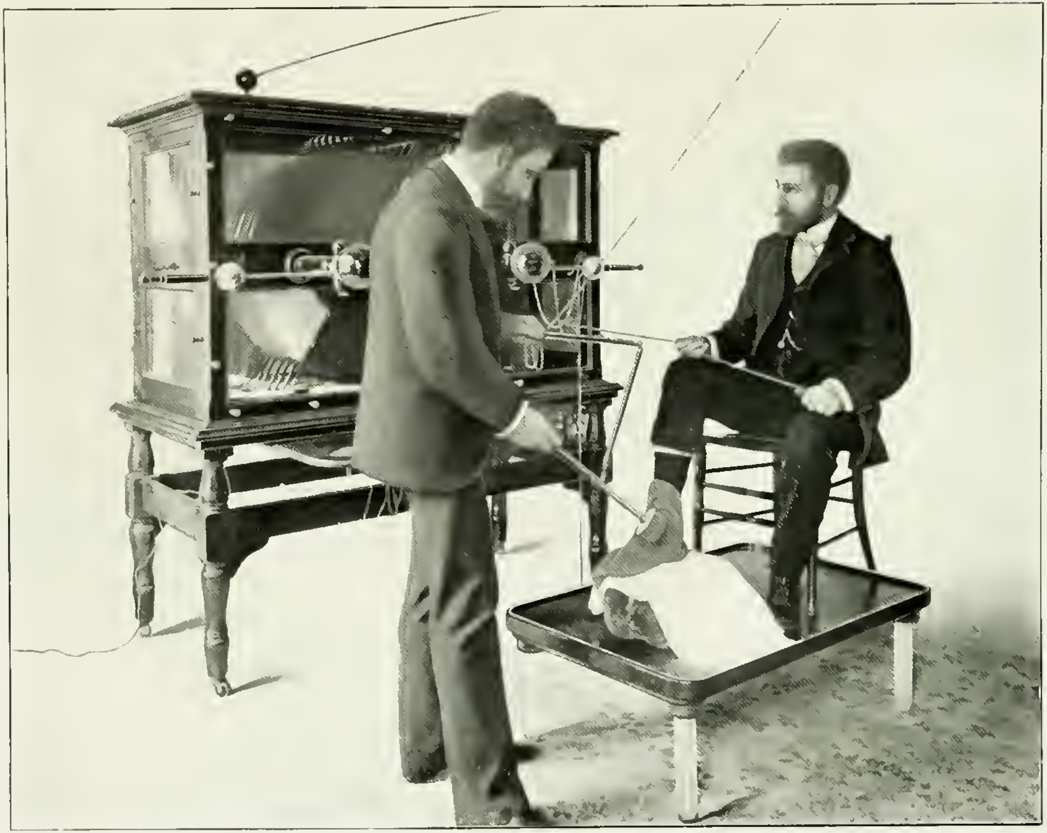

PLATE XV.

Movable Negative Spray to Ankle.

Physiology of Alternating Currents

AND

Hydro-Electric Methods.

FARADIC CURRENTS.

ESSENTIAL FACTORS.

1. Comparison of the Three Currents.—The phenomena of cataphoresis and electrolysis do not come within the domain of faradic currents. They are mechanical in their physiological effects, and are well nigh devoid of chemical action. The various manifestations of electricity employed in medicine and surgery—the faradic, the galvanic, and the static—differ only in the comparative value of their volume and pressure. In any of these forms it is electricity excited and modified in different ways. The galvanic current has low voltage and comparatively large volume; the faradic current has comparatively high voltage and very small amperage. The static current has a very high voltage (many thousand volts), and the volume is only a fraction of a milliampere. The varying ratio of these two physical qualities, pressure and volume, explains the different effects produced in animal tissues by these three currents.

2. Interrupted Induced Current.—The faradic current as used in medicine is not an alternating but an interrupted induced current. Interruption and induction are

§ 7

inherent in its evolution, from one or more galvanic cells, used in the primary circuit, to the completely transformed current at the binding-posts of the secondary coil. By special mechanical devices, the low electromotive force and large amperage of one or more galvanic cells is transformed into a current with a high electromotive force, and with a current-strength of but a fraction of a milliampere. What is lost in current-strength is gained in voltage. The energy of the current in the process of transformation loses 25 per cent. Its total volt-ampere capacity is reduced this much. It is wasted in the production of heat. There are, then, in the formation of the faradic apparatus, the following essential factors: (1) one or more galvanic cells; (2) the primary coil, with its core of soft-iron rods; (3) the vibrator; (4) the secondary coils.

3. Cells Used in Primary Circuit.—The cells used in the primary circuit may be either the Leclanché, the bichromate, or the dry cells. On account of the slight resistance in the primary circuit, these cells deteriorate quickly, and need to be looked after quite often. This rapid action in the primary circuit explains why cells arranged for the galvanic current should not be used to supply the faradic battery. The best cell for actuating the coil-current is a modification of the Leclanché cell, known as the *Samson* cell.

4. The Primary Coil.—The primary coil, with its interrupter and core of soft-iron rods, changes the galvanic current from the chemical cells into an induced current with the higher voltage and lower amperage. What is known as the *extra*, or *primary*, current is the break-current coming from this coil. It is unidirectional, and is an induced current. Its voltage is higher than that of the original galvanic cells, and its amperage much smaller. There are two primary binding-posts on faradic batteries, from which this current may be taken and applied in medicine. The important fact to remember is that this primary current is not a galvanic but an interrupted induced current with a higher voltage and lower amperage than the cells in circuit. It has a marked polarity, which may be readily tested by holding large well-moistened

electrodes in the hands. In using the primary current percutaneously, large well-moistened electrodes are employed to cut down cutaneous resistance. This compensates for the low voltage, and facilitates current penetration. The power of any current to penetrate tissues depends on its E. M. F. and the resistance of its circuit.

5. The Vibrator.—The vibrator is a vital part of every faradic apparatus. Without it there would be no current. On its smooth and even action, on the rapidity and slowness of its movements, depends much of the therapeutic work of coil-currents. There should be at least two adjustable vibrators, one for rapid vibrations, the other for slow. Slow vibrations include from 50 to 150 periods per minute, giving the muscle time to rest between each alternate contraction and relaxation. The slow vibrator may be adjusted so that it gives from 200 to 2,000 periods per minute, producing muscular massage. The rapid vibrator should be capable of attaining a maximum rate of from 12,000 to 20,000 periods per minute. To do good work, they must receive careful attention. They must be well polished, thoroughly freed from oxidation, and always kept in good working condition. Starts and jerks in the vibratory movement are very often unpleasant and sometimes harmful, and are always to be attributed to imperfect mechanism or to want of proper attention on the part of the operator. A single non-adjustable vibrator does not belong to the faradic apparatus employed in modern therapeutics. Such a vibrator is of little use in the treatment of disease. When the indication for treatment is to procure sedation, a vibrator that is slow, jerky, and irregular does harm. To obtain the best sedative effect, the interruptions should be rapid (15,000 to 20,000 a minute), perfectly smooth, even, and regular.

6. High-Tension Faradic Battery.—The modern high-tension faradic battery for use in general or special therapeutics should have more than one secondary coil. The Dubois-Raymond battery has a movable secondary coil. It is provided with two or more secondary coils made of wire of different lengths and sizes. The Apostoli battery has two

secondary coils—one coarse, the other fine. It is worked by two bisulfate-of-mercury cells, and is easily carried about. The secondary coarse-wire coil is No. 21 American gage and 45 meters long. The secondary fine-wire coil is No. 33 wire and 450 meters long. The Engleman battery has three secondary coils. The secondary coarse-wire coil is No. 16 American gage and 66 meters long; the intermediate coil is composed of No. 21 wire and 198 meters long; and the fine-wire coil is of No. 31 wire and 600 meters long.

SEDATIVE PROPERTIES.

7. The Engleman Battery Improved by Doctor Goelet.—For the sedative properties needed in gynecological practice, these batteries are not efficient. To provide these sedative properties, Doctor Goelet suggested the following improvement in the Engleman battery: All the different wires are wound on one spool, movable over primary, and having a rheostat adjusted in the circuit of the generating-coil. 238 yards of No. 21 wire are first wound on the spool. This is divided into two lengths of 84 yards and 154 yards. Next is wound 800 yards of No. 32 wire, which is divided into 300 and 500 yards, which, with the total 800 yards, gives three lengths to this coil. Next over this is wound 1,500 yards of No. 36 wire, divided into 500- and 1,000-yard lengths, giving three divisions of this wire: 1,500 yards, 1,000 yards, and 500 yards. The different lengths of this coil terminate upon a hard-rubber head at one end of the spool, and the selection is made by means of two movable levers, or arms. The Samson cell is the best for operating the induction-coil, four cells being connected in series.

8. Monell's High-Tension Induction-Apparatus. This is the only battery manufactured having a rheostat in the secondary circuit. The rheostat consists of two glass tubes marked *1* and *2*. They contain compound fluids, one of high resistance, the other of low resistance. The resistance of tube *1* is 1,000,000 ohms, and controls the electrical energy of the full-coil high-tension current, and reduces the perception of it

to zero in the most delicate application to a patient. The tube marked *2* has a resistance of 55,000 ohms; it is to regulate currents of less potential and for gynecological uses. Either of these tubes may be selected at will by a switch. These resistance-tubes control the secondary current independent of the primary. Tube *2* is used in making applications through high resistances. The same result is accomplished in both cases; viz., the perception of the electrical energy of the coil used is reduced to zero or increased to the point of tolerance.

9. This battery is provided with two adjustable vibrators, the one for rapid, the other for slow vibrations. They are both actuated by a single magnetic field and are entirely independent of the current in the secondary circuit. Both vibrators are thrown in or out of action by the movement of a single switch.

The slow vibrator may be adjusted to give any number of vibrations from 60 to 2,000 a minute. The majority of muscle-contracting applications call for a rate of about 75 per minute. The high rate of interruption obtained by adjusting the slow vibrator is utilized in practice to produce massage effects. The rapid vibrator may be adjusted to give a rate of interruption from 3,000 or 4,000 to 20,000 periods a minute. Both vibrators start into action when one or more cells are switched into circuit. If they lose their spontaneity of action, look for oxidation. The finer therapeutic qualities of coil-batteries depend on superior mechanism. This is particularly applicable to the mechanical construction of the vibrator. A crude vibrator will spoil the work of the best coil.

10. To the possessor of a static machine it is here recommended to study the effects of different rates of interruptions, by approaching a grounded electrode to the prime conductor. By causing the plates to rotate slowly or rapidly, and by holding the grounded electrode at varying distances from the prime conductor, the effects of very slow interruptions or interruptions so rapid as to produce effects very similar to continuous currents are very clearly demonstrated. From 15,000 to 20,000 interruptions a minute is the maximum rapidity attained by any faradic vibrator; but with the static current

and a grounded electrode, any number of interruptions, from one in any number of minutes to a million or more a minute, are readily attainable.

11. Behind an upright switchboard, and invisible to the patient, is a compound Kidder coil. The secondary coils are permanently fixed over the primary, so that no sliding movements are required. The secondary coils contain 8,000 feet of Nos. 21, 32, and 36 wire, making 15,000 turns, and tapped at approved lengths. Six dry cells are fitted in the case, and any number of these cells can at will be switched into circuit. The binding-posts on the switchboard may be connected with outside fluid-cells if the physician wishes. By the movement of a key on the switchboard, the primary and secondary coils may be united.

12. Secondary-Current Controller.—The advantage of a secondary-current controller is in regulating the application. By its means the current can be gradually applied from the slightest sensation beneath the electrode to the toleration of the patient. A secondary coil has not acquired its full therapeutic properties until it is submitted to the entire inductive influence of the primary coil. To do this, it must completely overlap the primary coil. It is always better to have the secondary coil fixed over the primary, and then regulate the current through the secondary-current controller.

13. Qualifying Conditions.—The electromotive force and amperage of any coil-current depend on the inducing current and the length and cross-section of the secondary coil. The longer and finer the secondary coil, the greater its voltage and the less its volume. Multiplying the windings increases the voltage. and increasing the length of the wire increases the resistance, and therefore cuts down the volume of the current. When the secondary coil is only partly over the primary, the resistance of the secondary coil remains the same, while its voltage is reduced.

14. Interruptions of Induced Current.—The rate and character of the interruptions of the induced current have so

much to do with its therapeutic properties that some ready way of testing them is very important. If the bipolar vaginal electrode is held in the hand, and the current turned on from different coils and at different rates of interruption, with different electromotive forces and different resistances, any jerk or uneven action can be detected, and the effect of alterations in E. M. F. and resistance may be studied. The telephone forms a ready test, and through it the quality of the interruptions is closely studied. Any length of coil may be connected with the telephone, and, with the receiver placed to the ear, the quality of the interruptions with slow and rapid vibration, with coils of wire of different lengths and sizes, may be studied and regulated at will.

15. Geissler's Tube-Test for Unevenness of Interruptions.—Connect a Geissler tube with the binding-posts of the faradic apparatus, and any jerks or unsteady movements of the vibrator will be reflected in the motion of the disks.

16. Determining the Length and Sectional Area of Wire Used in Any Coil.—Connect the coil to be tested with the binding-posts of a galvanic battery, and turn on the current until the milliammeter registers 5 or 10 milliamperes. Now switch off the coil, and in the circuit place coils of German silver wire of known resistance, until the needle comes back to the position it occupied with the coil to be tested in the circuit. This will then be the resistance of the coil. These resistance-coils are furnished with a cabinet apparatus. Knowing the resistance of the coil, the length and the sectional area are quickly determined by consulting the table of resistances (page 8) of different sizes of copper wire, according to Brown & Sharpe's American gage. A coil of No. 36 wire that has a resistance of 200 ohms contains 480 feet, or 160 yards. The result is obtained by multiplying the number of ohms resistance by the number of feet per ohm of the wire, according to the table.

17. Geissler's Tube-Test for High E. M. F.—This test is made in a darkened room. By means of a short piece of copper wire, connect a Geissler tube about 4 inches in length

with the opposite binding-posts of the faradic apparatus. If the whole electromotive force of the finest and longest coil fails to glow the tube, the battery does not possess the quality known as high tension. It requires about 4,500 feet of

TABLE OF RESISTANCES OF DIFFERENT SIZES OF COPPER WIRE, ACCORDING TO BROWN & SHARPE'S AMERICAN GAGE.

Gage Number.	Weight. Feet per Pound. (Silk-Covered.)	Ohms of Resistance per 1,000 Feet.	Feet per Ohm.
14	75	2,504	400.0
15	95	3,172	316.0
16	120	4,001	230.0
17	150	5,040	198.0
18	190	6,360	157.0
19	240	8,250	121.0
20	305	10,120	99.0
21	390	12,760	76.5
22	490	16,250	61.8
23	615	20,300	48.9
24	775	25,600	39.0
25	990	32,200	31.0
26	1,265	40,700	24.6
27	1,570	51,300	19.5
28	1,970	64,800	15.4
29	2,480	81,600	12.2
30	3,050	103,000	9.8
31	3,920	130,000	7.7
32	4,930	164,000	6.1
33	6,200	206,000	4.9
34	7,830	260,000	3.8
35	9,830	328,000	2.9
36	12,420	414,000	2.4

No. 36 wire, American gage, to glow a Geissler tube. The longer and finer the wire, the more brilliant will be the luminosity of the tube. The only reason why a medical high-tension induction-apparatus will not glow a Crookes tube is that it has not sufficient E. M. F. to overcome the resistance of the vacuum.

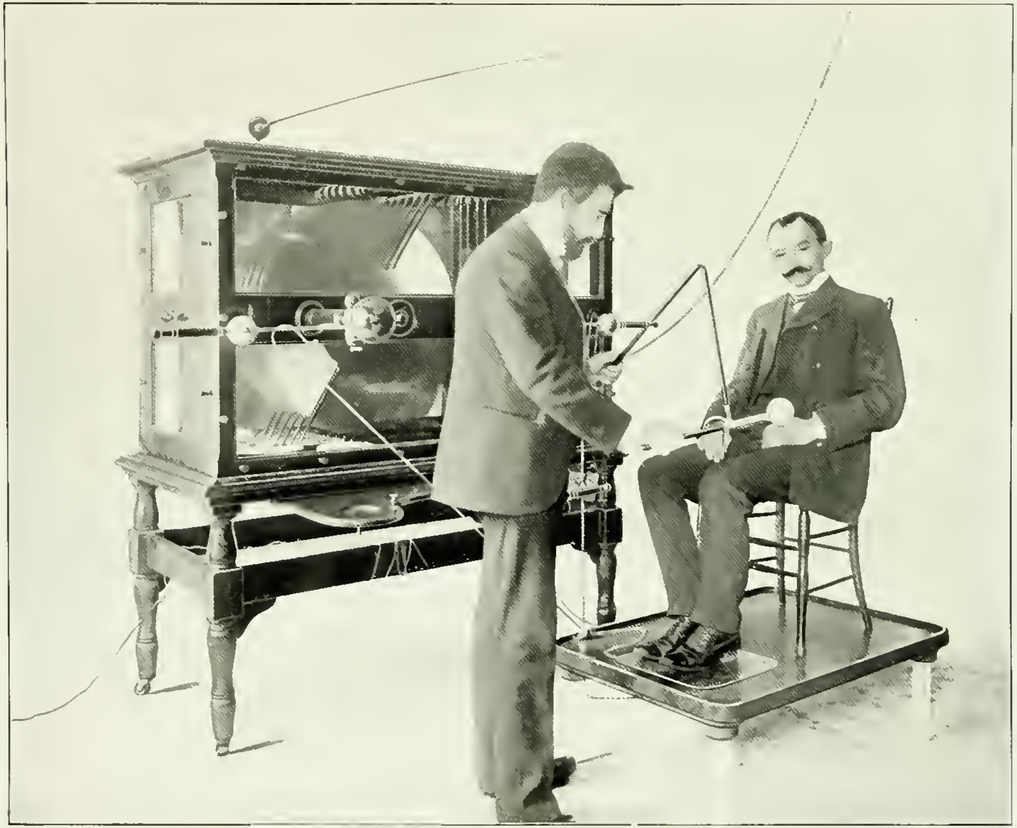

PLATE XVI.

COIL-CURRENTS.

18. Polarity of the Induced Current.—That the poles of the coil-current have different action may be readily proved. Place the negative pole over a motor nerve, and turn on the current until a slight contraction is noticed. Reverse the polarity, and the positive pole has no action; it produces no contraction. Place the negative pole over a slight abrasion on the skin, and turn on the current. The negative pole will be found to irritate and be painful. Now try the positive pole placed over the same abrasion, and it will be found to be soothing and to allay pain. Its action is on the motor, vasomotor, and sensory nerves. The polar action of the induced current is very distinct. It is mechanical and physiological in its nature, having no cataphoric or electrolytic action, like the poles of the galvanic current. The importance of the position of the poles will be pointed out in studying the action of the induced current on the vasomotor nerves. The faradic current with its decided polarity has a distinct advantage over the alternating currents in the treatment of disease. The external resistance is an important factor in producing the physiological effects of coil-currents.

19. Effects of Fine and Coarse Coils.—The different effects of the long fine coil and the short coarse coil, both operating through low resistance, may be well observed in making a vaginal application in a healthy woman. Place in the vagina the bipolar vaginal electrode connected with the long fine coil; its action will be agreeable and sedative. Now disconnect the electrode, and join it to the short, coarse coil; the effect will be altogether different. The sharp, strong contraction produced will be painful. Now, with the same coil-currents make a percutaneous application. The effects produced percutaneously like those produced permucous will be found to vary with the alterations in the electromotive force, with the changes in current-strength, and the varying resistance of the tissues. It will be readily understood that a current of high voltage will penetrate more deeply than a current of low

voltage, the resistance remaining the same. If a current penetrates more deeply, it is more diffused; its action is spent on a larger tissue area; it must necessarily be milder and more sedative than if it were limited to a smaller area. The coarse-coil current lacks penetrating power, on account of its lower voltage. It is limited to a small area of tissues, and hence its stimulating quality. The long fine coil, by virtue of its high voltage, penetrates deeply, diffuses into tissues, affects a large area, and is sedative in its quality. The current from any coil will vary with alterations in the inducing force, in the rapidity of interruptions, and with the resistance in circuit.

20. Action of Slowly Interrupted Current.—A slowly interrupted faradic current, from 30 to 150 periods per minute, produces a series of muscular contractions. Between each successive contraction there is relaxation and an interval of rest. The muscle is allowed time to regain itself. This is physiological activity, and has a marked effect in the improvement of nutrition. Tetanic contractions produce muscular anemia, and if repeated, will in time produce physiological degeneration. When treating a paralyzed muscle or nerve, the tetanizing action of the coil-current would simply make neuromuscular nutrition worse. On this point the experiments of Debedat are instructive. He stimulated with coil-currents for 4 minutes each day for 20 consecutive days a group of muscles of one leg of a rabbit. At the end of 20 days the stimulated group compared with the group on the other side had gained 40 per cent. This 40 per cent. represented true physiological growth.

21. Action of Rhythmic and Continuous Currents. Tetanizing the muscles, without any interval of repose, produced in the same animals histological degeneration. Stimulating the muscles with a slowly interrupted galvanic current of 2 milliamperes strength showed a gain of 18 per cent. Galvanic currents of the same strength, applied without interruption, produced very little increase in nutrition. Stimulated by electrostatic sparks there was no observable result. From these experiments he concludes that moderate exercise from rhythmic coil-currents, each contraction followed by a period of repose,

produces the best effects. The results of rhythmic galvanic currents show considerable improvement in nutrition, but the continuous galvanic current has little or no effect. The difference between the rhythmic and the continuous action of the galvanic current in these experiments is striking. The interruptions in the galvanic current disperse the products of electrolytic decomposition, and permit more vigorous interchange between blood and muscle. By dispersing accumulated products, the chemical changes between blood and muscle receive a fresh impulse, and nutrition is increased. Static sparks were followed by no enduring results.

22. Effects Produced by Slow and Rapid Interruptions.—A slowly interrupted faradic current produces isolated muscular contraction, with increase in nutrition and increase in physiological development. A rapidly interrupted coil-current tetanizes muscles, and produces muscular anemia and histological degeneration. Interruptions varying from 200 to 3,000 periods per minute cause electric massage, and are much used in pelvic inflammatory troubles when pain is not a symptom. They do not produce sedative effects, and are not adapted to stimulate groups of muscles when the object is to improve nutrition. The utility of coil-currents in the treatment of diseased conditions is not limited to their power of contracting muscles. Indeed, they often appear more effective than the direct current when judiciously used in neuromuscular maladies attended with reaction of degeneration.

23. Slowly interrupted coil-currents have very little action on non-striated muscles, but when rapidly interrupted, the non-striated muscle-fiber responds vigorously. Each fiber contracting successively, the normal vermicular movement of the arteries and arterioles is stimulated. This accelerates the flow of blood and lymph through the tissues, relieves venous stasis and areas of congestion, promotes absorption, and increases the elimination of waste material.

24. Use of Coarse-Wire Coil.—As a muscle-stimulator, the current from the coarse-wire coil is to be preferred. When

using the coarse-wire coil, on account of its low voltage, the resistance of the tissues should be lessened by using large electrodes and thoroughly saturating the skin. In uterine subinvolution, the infiltration between the bundles of muscle-fibers decreases uterine muscular contractility. In these cases the current from the coarse-wire coil, on account of its greater amperage, and therefore greater stimulating property, is particularly indicated. The low resistance of pelvic tissues is suited to the low voltage of the coarse-wire coil, and the greater amperage or stimulating property of the coarse-wire coil adapts itself well to the decreased uteromuscular contractility.

25. Use of Fine-Wire Coil.—In large, soft myomas, Doctor Massey speaks well of the action of the primary current in producing muscular contraction. The rapidly interrupted current from the large fine-wire coil may also be used to contract muscles, but its chief use is to establish local unconsciousness, to allay pain, and to procure sedation. How the rapidly interrupted current from the fine-wire coil allays pain and procures sedation is not yet satisfactorily determined. Doctor Goelet claims it is due to a temporary paralysis of the motor and sensory nerves acted on by the current. The relief of pain that follows the application of these currents, in the manner described for producing sedation, may be explained in this way, viz., the rapid succession of impulses imparted by the interruptions may be regarded in the nature of a percussion that induces a condition of concussion of the nerve-filaments, impairing their condition to conduct painful impressions. The intense stimulation of the motor nerves produces a tetanic contraction of the muscles which eventually wears out their contractility, producing relaxation, or a temporary local paralysis that means rest for the diseased parts they encompass. It is probable, also, that relief of the congestion on which the pain may, in a great measure, depend, is another way in which this result is reached.

26. Sedative Properties of Rapidly Interrupted Current.—Both muscles and nerves, by the tetanizing action of the current, have their irritability rapidly exhausted.

Apostoli attributes the sedative effects to the direction in which the electric impulses travel. He supposes they are in a direction against the impulses of pain, and in that way annul their effect. Dr. W. J. Morton explains the sedative properties of the rapidly interrupted current, by assuming that the nerve-filaments of the area acted on by the current are in a condition resembling that of cerebral concussion. The current acts mechanically, by producing a commotion like that caused by a blow or an injury to the cerebrum. A strong faradic current from the long fine coil, rapidly interrupted, tetanizes the muscles, both striated and non-striated, exhausts rapidly neuro-muscular irritability, and destroys pain. As a sedative benumbing agent, this current is much employed in gynecology. Its pain-relieving properties in pelvic maladies are second only to opium. Its properties to stimulate muscles are used in various diseases of the neuromuscular system.

27. Fatiguing Quality of Current.—The fatiguing quality of the current is employed in the treatment of spasmodic contractions and in hysterical contractions. The current is applied to the contracted muscle until it is thoroughly relaxed. Contraction takes place again shortly after the treatment, and the applications must be continued daily until a cure is effected. The current will give good results in this way in many orthopedic cases. *In using coil-currents from either the coarse-wire coil or the fine-wire coil, whether with fast or slow interruptions, fix clearly what it is desired to accomplish, and with this end in view apply the current.* The effects of high-tension induction-currents on body nutrition have been very clearly investigated within recent years. M. D'Arsonval's experiments show that general faradization increases respiratory functions by stimulating the muscular system and also the sensory nervous system. General faradization, therefore, increases nutritive changes either with or without muscular contraction.

28. Retardation of Nutrition.—Analysis of urine made by Dr. Berlioz proves the efficacy of high-tension induction-currents in all those diseases characterized by retardation in the processes of nutrition. The increased activity in oxidation

was shown in the diminished amount of uric acid and the increased amount of urea eliminated. Mineral products and organic waste are also better eliminated. These currents increase the appetite and improve digestion. Return to natural sleep with a renewed power for work, both mental and physical, are among the effects first noticed. The diseases most amenable to treatment by these currents are gout, rheumatism, and diabetes.

29. Action on Muscles.—When both electrodes are applied directly to the skin, the action of rapidly interrupted currents depends on the electromotive force. With moderate E. M. F. the reaction is principally on the skin, which becomes reddened, due to the stimulation of the vasomotor nerves. There is also a pricking sensation, due to irritation of the sensory nerves. With increasing E. M. F. the muscles beneath the skin are thrown into tetanic contraction, which, if persisted in, will quickly produce fatigue and exhaustion. The neuromuscular response will be quicker and more energetic if the electrode is placed over a motor point. Changing the position of the electrode rapidly from one motor point to another, or touching the same motor point at as short intervals as possible, causes an agreeable tonic exercise of the muscles, which restores lost tone and gives renewed energy to fatigued muscles. This action of the tetanizing current on muscles is very important and deserves special attention. A large part of the therapeutic action of coil-currents in human tissue depends on their power to contract muscle-fiber, and on the rapidity and varying durations of these contractions will depend the different effects produced.

30. Vasomotor Effects of Current.—If a tetanizing contraction is long maintained, fatigue and exhaustion must follow. But when the tetanizing action is only momentary, as when the electrode is rapidly shifted from one motor point to another, the blood- and lymph-currents within the muscles are accelerated, the muscles receive an increased supply of oxygen, and thus energy and vitality are quickly restored. The lightness and buoyancy experienced in the muscles thus exercised

are due to the vasomotor effects of the current in increasing the supply of oxygen to the muscles, giving new life and energy.

31. Vermicular Action.—Rapidly interrupted induction-currents produce a vibratory movement in the protoplasm of the body, and, as protoplasm constitutes nine-tenths of the body, and nine-tenths of its most vital parts, the influence of these currents may be better appreciated. The vermicular motion of the blood-vessels and intestines is increased in the direction of the current. Polarity must therefore be considered when the effects of these vermicular movements are required. The vasomotor nerves and the visceromotor nerves are very actively stimulated by rapidly interrupted currents. Stimulation of the visceromotor nerves increases the peristaltic action of the intestines, accelerates the blood-current in the intestines, promotes intestinal secretions, and relieves constipation. They increase the secretions of serous surfaces, for by them a dry and creaking joint may be made to secrete. Glandular secretion in general is stimulated, and the entire sympathetic system comes within its range of action. The physiological action of these currents on the vasomotor, visceromotor, and secreting nerves explains its therapeutic use in a wide range of diseases.

32. Pelvic Effects of Currents.—The pelvic effects of currents both from the coarse and the fine coil require special attention. The mucous tissues of the pelvis conduct electric currents with the same facility as saline solutions. This good medium of conductivity is surrounded by a bony wall—a poor conductor; hence it is that the electric current permeates all of the pelvic viscera. The bipolar method of treatment, dispensing with the inconvenience and pain of the unipolar method, has done much to popularize the use of electricity in pelvic diseases. The bipolar method permits also the use of much stronger currents than were heretofore used, and concentrates them on the organs to be treated. Resistance is still further diminished by placing both poles near each other on the same electrode.

33. Uterine Treatment.—The vagina and uterus are comparatively insensitive to electric currents, and much stronger currents can be used, since the painful cutaneous

surface is eliminated, and the resistance is less than that of the skin. The electric current must not be turned on until the electrode is well placed within the uterus or within the vagina, and it must be supported there by the hand during the séance, and must not be removed until the current is turned off. Special care should be taken to see that the external pole of the electrode does not come in contact with delicate, sensitive structures at the vulvo-vaginal junction. The poles of the bipolar vaginal electrode are $1\frac{1}{2}$ inches apart, and those of the uterine electrode are 1 inch apart. The internal os is very sensitive to the electric current. Both poles of the uterine electrode should therefore be well within the body of the uterus before the current is turned on, and should be maintained there by the hand during the entire séance and until the current is turned off. By observing these few details the patient may be spared much pain.

34. The current from the coarse-wire coil is used to stimulate and contract the muscles in the pelvis. This current was particularly studied and developed by Tripier, as the fine-coil current was by Apostoli. Flections are corrected and the development of the uterus increased. Passive congestion and subinvolution are removed by the stimulating and contracting powers of coarse-wire currents. A large relaxed discharging uterus, under the use of this current, soon regains tone and diminishes in size, while the endometrium returns to its normal condition. In using the coarse-wire coil for these purposes, slow interruptions alone are used. Relaxed pelvic tissues from any cause, and relaxed vaginal walls, are amenable to treatment by this current. The chief pelvic effect of the fine-wire coil-current is to relieve pain and congestion. The pelvic effects of the current from the fine-wire coil depend on the method of administration, strength of current, and the rate and quality of interruptions. When stimulation is desired, short applications are the rule. When sedation is required, the séance should last from 15 minutes to $\frac{1}{2}$ hour, and the current must be turned on gradually and evenly. There is not much danger of producing too much sedation.

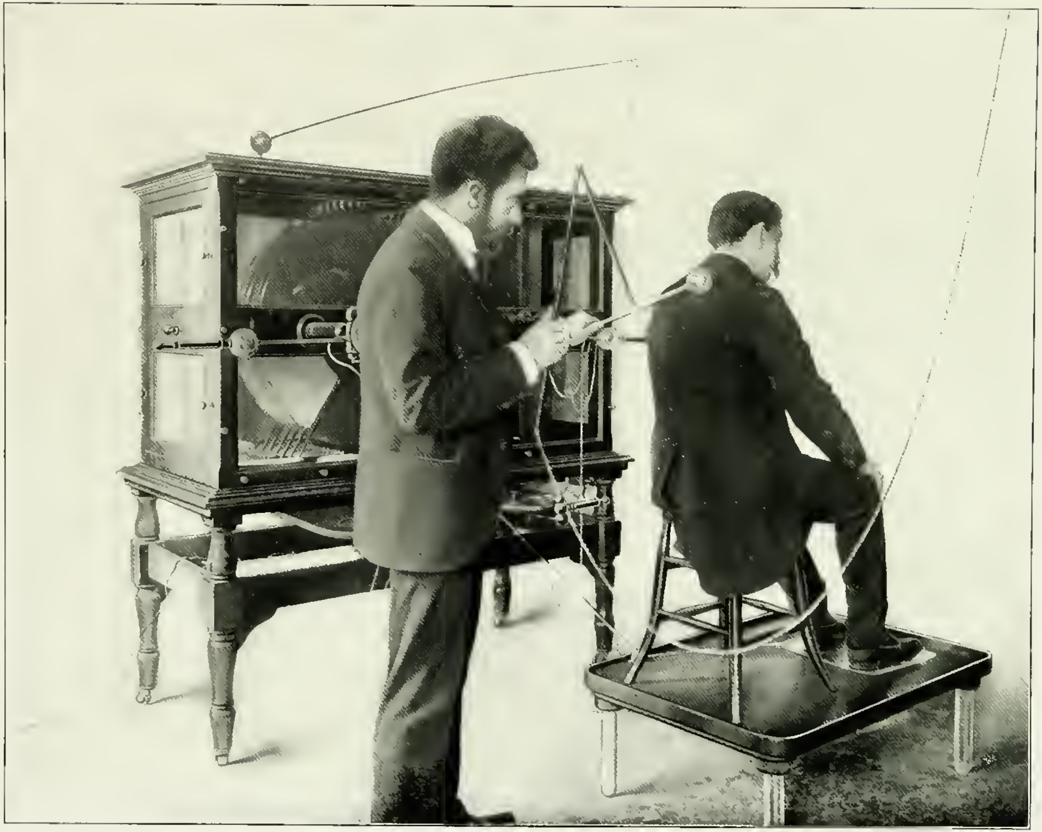

PLATE XVII.

Frictional Sparks to Spine.

35. Massage Effects.—To produce massage effects, interruptions varying from 1,000 to 2,000 per minute are used, and the séance must be short. To procure sedation, the maximum rapidity attainable is used, and the séance should be long. The current from the long fine-wire coil may be made stimulating by increasing its strength rapidly and maintaining the strength at a point where it is felt throughout the entire séance. For this purpose the application should not be prolonged beyond 5 or 10 minutes. A sedative application may be converted into one that is stimulating by changing the number of vibrations per minute. Extremely rapid vibrations are sedative; coarse vibrations from the long fine-wire coil are stimulating.

36. Summary.—When the indication for treatment is principally to act on the circulation, the unipolar method should be used, because the circulation is increased when it has the same direction as the current, and vice versa. Acute inflammatory conditions of the ovaries, tubes, or periuterine tissues are much benefited by the current employed in this manner. The pain is allayed, congestion relieved, and the exudations and infiltrations are absorbed. They impart a tonic condition to all pelvic viscera. The principal facts to remember in applying coil-currents to the treatment of pelvic maladies are:

1. The primary current may be used to produce muscle-contraction.

2. The coarse secondary coil is irritating and muscle-contracting, and with interruptions varying from 1,000 to 2,000 per minute, massage effects are produced. The séance should be of short duration.

3. The long fine-wire coil may be used to contract muscles, the contractility of which is not impaired, but its chief use is to allay pain and produce sedation. When used to produce sedation, the séance should last from 15 minutes to $\frac{1}{2}$ hour.

4. By making the interruptions coarse, the current from the long fine-wire coil becomes irritating.

5. By increasing the current-strength rapidly, and maintaining it at a point where it is perceptible during the whole

séance, the fine-wire coil-current is rendered irritating; and is indicated to produce absorption of inflammatory material and effete products where the pelvic tissues are not sensitive.

PERIODIC INDUCED CURRENTS.

37. Periodic Induced Currents in Gynecology. Under this name Dr. A. H. Goelet has grouped three different currents, each derived from an apparatus of special construction. These currents are named as follows: (*a*) the interrupted induced current, derived from the long fine-wire coil of the scientifically constructed coil-battery; (*b*) the sinusoidal current, derived from the sinusoidal machine; (*c*) the static induced current derived from the static machine with Leyden jars in circuit.

38. The static induced current, on account of the bulk and weight of the static machine, is restricted entirely to office-practice.

The sinusoidal machine is non-portable, somewhat costly, and requires the street current for its operation.

39. The scientifically constructed coil-battery provided with dry cells is portable, comparatively cheap, and the current from its long fine-wire coil fulfils perfectly all the therapeutic uses of the currents from the other two machines.

40. Stimulating Property of Periodic Induced Currents.—The most noticeable effect of periodic induced currents is a muscle, nerve, and circulatory stimulation, the latter depending mainly on the action of the vasomotor supply. The degree and nature of this stimulation depend on the E. M. F. and amperage of the current employed and the rapidity of the impulses imparted by the interruptions. In the coil-battery, the stimulating property of the current is governed by the length and size of the wire composing the secondary coil, which regulates the E. M. F. and amperage of the secondary current, the force of the primary current being constant, or very nearly so. The rapidity of the interruptions is controlled by

the automatic vibrator in the primary circuit. The advantage, then, of a number of secondary coils, having different lengths of the same wire and different sizes of wire, is that the stimulating property of the current may be conveniently and gradually increased and decreased.

41. Stimulating Property of the Alternating Current.—In the sinusoidal machine now on the market, the windings are all the same; hence, the stimulating property of the current, which is a secondary, depends on the strength of the current supplied to the primary fields. The E. M. F. and rapidity of alternations are increased by increasing the speed of the machine—that is, by increasing the revolutions of the armature or revolving disk. The volume of the current cannot be greatly varied.

42. Stimulating Property of the Static Induced Current.—In the case of the static induced current, the stimulating property of the current depends on the size of the Leyden jars and the distance between the discharging-rods; that is, the size of the jars represents the volume of the discharge, and the air-gap between the discharging-rods regulates the rapidity of the impulses. The amperage and rapidity of interruptions of the current are regulated in the same manner as the currents from the coil-battery, the small-, medium-, and large-sized jars taking the place of the coarse-, medium-, and long fine-wire coils of the battery.

43. Comparison of Currents From Coarse and Fine Coils.—The marked difference in the effect produced by currents derived from the long fine-wire and the short coarse-wire secondary is just what would be anticipated from their different natures and properties, the former being a current of low E. M. F. and greater volume, and the latter possessing a high E. M. F. but an almost inappreciable volume. As shown by Duchenne, the current from the short coarse-wire coil acts more directly on the muscles (lacks penetrating power), increasing their contracility, and is more localized; and the current from the long fine-wire coil acts more especially on the sensory nerves and penetrates more deeply. It may

further be said that the current from the long fine-wire coil diminishes muscular contracility; for, though the first effect may be that of a stimulant, it is secondarily sedative. The immediate effect of both forms of this current is therefore a stimulation; but the one, the current of volume, produces muscular stimulation, and the other, the current of tension or high E. M. F., produces a nerve stimulation; and, in employing periodic induced currents, these facts must be borne in mind.

44. Effects Produced by Coil-Currents.—One of the most important effects produced by these currents is an increase in tissue metabolism, increased absorption of oxygen, and a corresponding increased elimination of carbon dioxid by the tissues and coincidently increased nutrition. They therefore accelerate the functional activity of organs brought under their influence. This effect of the current can be readily demonstrated. Its power to increase perspiration may be shown by grasping in one hand the bipolar vaginal electrode, and using the fine-wire current as strong as it can be borne for a few moments. The hand becomes bathed in perspiration. At the same time, another very important phenomenon will be observed; namely, the hand, but more particularly the fingers, soon become pale and bloodless. This pale, bloodless condition of the hand and fingers is due to the tetanic contraction of the muscles and to the effect of the current on the vasomotor supply. This one simple experiment very strikingly illustrates the action of alternating currents on the vasomotor nerves. This influence of alternating currents on the vasomotor nerves is of the first importance in the electrical applications of pelvic diseases. Improvement in the general health out of all proportion to that of the local condition has often been noted, even when only local applications have been made to the female pelvic organs.

45. Capillary Circulation Stimulated by Alternating Currents.—The power of alternating currents to promote rapid absorption of inflammatory exudates may be attributed directly to stimulation of the capillary and lymphatic circulation. Alternating currents stimulate the capillary circulation:

1. By exciting an increased vermicular contraction of the smaller arteries, the blood-pressure is augmented. This causes momentary distension of the capillary vessels, the reaction from which, owing to their elasticity, empties or unloads them into. the veins. In case of any obstruction in the capillary vessels, this distension, together with the increased blood-pressure, favors its removal.

2. By stimulating the contraction of adjacent muscles, the veins are emptied, and a void is created in their intervalvular spaces, which invites the blood from the overloaded capillaries.

46. Lymphatic Circulation Stimulated by Alternating Currents.—Alternating currents stimulate the lymphatic circulation in two ways:

1. By stimulating the processes of absorption.

2. By stimulating the contraction of adjacent muscular structure, with the effect that the circulation in the lymphatic vessels is increased. These vessels being supplied with valves similar to those found in veins, the contraction of surrounding muscles empties the intervalvular spaces, and invites the flow of lymph from the lymph-spaces when absorption takes place. As the result of this action on the capillary circulation and lymphatics, pelvic congestion is relieved and rapid absorption of infiltrations and exudations is accomplished. The alternating current is unquestionably the most powerful, the most certain, and therefore the most valuable vasomotor constrictor that we possess.

47. Sedative Effects of Alternating Currents.—Perhaps the most important effect of alternating currents of high E. M. F. and great frequency is the production of sedation and the relief of pain. As pointed out by Duchenne, the special action of these currents is on the sensory nerves, and it partakes of the nature of an excitation; but this excitation or stimulation will result in sedation if certain conditions are observed. This appears to involve an inconsistency, but it will be remembered that while opium is a cerebral and circulatory stimulant, yet its effect is sedative.

48. Rate of Interruptions Governed by Desired Effects.—The rapidity of interruptions has likewise an important bearing on the result, since the more rapid they are, the more soothing the result. Therefore, for a sedative effect they should be as rapid and as smooth as possible. In using the coarse-wire current for muscle-stimulation, the interruptions should be slow, so as to allow an alternate contraction and relaxation similar to the normal physiological action of the muscle.

49. Frequency of Applications.—The frequency of the applications and the subsequent behavior of the patient are also to be considered. Three times a week may be sufficient when stimulation is required, and the patient may not be restricted in her movements especially to attain this result. But sedative applications should be made every day, and in some instances several times a day; but, to be productive of the best results, they should be made after the patient has retired for the night, or she should be made to recline for at least an hour or two afterward. This is not always essential, however, for in very many instances the relief obtained continues for hours, even when the application is made in the physician's office and the patient is permitted to exercise moderately afterward.

50. Therapeutic Use of Coil-Currents in Female Pelvic Diseases.—As a therapeutic measure for the relief of pelvic pain and congestion, pelvic inflammation and their results, and infiltrations and exudations, this form of electricity is incomparable with any other agent that we possess. It is to be regarded not only as a remedy against the symptoms accompanying diseases of the female pelvic organs, but often as a curative agent as well, though frequently it serves only as an auxiliary to the other remedies. In cases where the disease is so far advanced that a cure cannot be effected, and some radical operation is necessary, it serves an exceedingly useful purpose in placing the patient in the best possible condition to withstand it, and aids its success by improving greatly the local condition and her general nutrition.

51. The coarse-wire current is particularly serviceable when there is loss of muscular tone and venous engorgement, such as in subinvolution; but it is absolutely contraindicated in sensitive and inflamed conditions.

MEASURING-INSTRUMENTS.

52. Coil-Current Measuring-Instruments.—The introduction of the milliamperemeter in electrotherapeutic practice lifted the direct current from empiricism and placed its therapeutic uses on a scientific basis. There is no instrument to take the place in measuring the strength of coil-currents that the milliamperemeter fills in measuring the strength of direct currents. How, then, can records of coil-applications in clinical work be so described that they can be easily comprehended and accurately repeated by physicians everywhere?

Dr. S. H. Monell is the author of the method that will be described here. He studies first the various factors involved in the intelligent description of any direct-current application. These factors are as follows: (1) The electrodes used, and the material used in covering their surface; (2) the situation of the electrodes during treatment; (3) the pathological condition treated; (4) the time and frequency of administration; (5) the milliampere-strength of current. If these different factors of direct-current applications are carefully described, separate observers can readily repeat and compare clinical results.

In order to place coil-currents on exactly the same basis, what factors should be described in every coil-current application? They are as follows: (1) The character of the current, stating the length and size of wire in the coil employed; (2) the electrodes used, and their location during treatment; (3) the rapidity of interruptions; (4) the pathological condition treated; (5) the time and frequency of administration; (6) the current-strength; (7) the number of cells in the primary circuit. All these separate factors, with the exception of the sixth, are readily described. The want of a scientific

means to determine the sixth factor, or the current-strength, has always rendered the comparison of coil-current applications by different observers very unsatisfactory.

53. A Scaled Rheostat to Measure Faradic Dosage. The millimeter-scale placed at the side of the coils is for various reasons very inaccurate and unscientific. As all other factors of faradic dosage can be sufficiently indicated for therapeutic purposes, the question is, How shall the current-strength be measured? The influence of the variations in the resistance of the skin over different parts of the body is insignificant when using the higher voltage and penetrating power of currents from induction-coil apparatus, and it is for this reason that a given E. M. F will generate a definite current-strength from a given induction-coil and repeat it under the same conditions, as often as desired. In coil-current therapeutics there are two resistances; namely, the skin and the mucous linings of the cavities of the body. The variations in resistance of both the skin and the mucous cavities need not be considered in faradic therapeutics, for they do not influence current-strength in any appreciable way.

To use the method of faradic dosage, a scaled rheostat in the patient's circuit is indispensable. This rheostat must be able to control the entire electrical energy of the coil used. The electrical energy of the coil is first expended in the rheostat, and when it is released from the rheostat, it is expended in the tissues of the part to which it is applied. The resistance of the body is compensated in this process, and the E. M. F. is unaltered during the dose-regulation. If the amount of electrical energy liberated from the rheostat is known in units of resistance, the amount of energy expended in the tissues is represented by the same resistance. "Things that are equal to the same thing are equal to each other." The therapeutic dosage may therefore be indicated by the number of ohms eliminated from the scaled rheostat in the patient's circuit.

54. Experiments With Doctor Monell's Scaled Rheostat.—A few experiments will make this method clear.

PLATE XVIII.

Perineal Sparks.

Experiment 1.—Two ordinary electrodes are held in the hands; the entire resistance of glass tube No. 1, or 1 megohm, is in circuit. Take 1,500 yards of No. 36 wire for the coil, and 4 cells in primary circuit; number of interruptions, 75. Now gradually approximate the electrodes of the rheostat until the current becomes perceptible to sensation. This may be at a point indicated by 700,000 ohms on the scale. This point is then taken as the zero-unit, and the electrodes are further approximated until the desired contractions in the arms are produced. This may be at a point indicated by 100,000 ohms. In producing the desired muscular contraction, 600,000 ohms have been removed from the passage of the current, and the electrical energy required to overcome this resistance was expended in the muscles of the arms. This experiment is recorded as follows:

Coil, 1,500 yards of No. 36 wire; interruptions, 75; E. M. F., 4 cells; *R*, 600,000 ohms. Ordinary sponge-electrodes held in hands, positive in right.

Any physician having an induction-apparatus with a scaled rheostat in the secondary circuit can repeat this application and muscular effect whenever and as often as he wishes. If the cells deteriorate by use, a larger number will be required to equal the energy recorded. The method is the same.

Experiment 2.—The ordinary electrodes are held in the hands. Take the coarse coil, 154 yards of No. 21 wire, 2 cells, and interruptions, 300. The current is perceptible to sensation when the rheostat indicates 36,000 ohms, and full tolerance is reached when but 4,000 ohms remain. The given dose is, therefore, the electrical energy represented in removing 32,000 ohms, and the current-quantity value is indicated by stating the length and size of the wire. This record will then read as follows:

154 yards of No. 21 wire; interruptions, 300; number of cells, 2; electrodes same as in Experiment 1; *R*, 32,000 ohms.

Experiment 3.—When making a bipolar vaginal application with the rapidly interrupted, high-tension sedative current, the low-resistance tube is used, owing to the low resistance of the pelvic tissues. An illustrative clinical record reads as follows:

Vaginal bipolar sedation; coil, 1,500 yards of No. 36 wire; rapid vibrator; E. M. F., 4 cells; *R*, 45,000 ohms; 20 minutes daily.

55. Doctor Monell's Claims for His Rheostat.—Concerning his method of recording faradic dosage, Doctor Monell writes as follows: "To be a scientific and universal method, it must answer for all conditions of treatment, and my method does this perfectly. The use of a single cell or any number of cells up to six (the battery contains six cells) will determine the zero at a higher and lower point on the scale, and the same cells, as they deteriorate, in time will alter their E. M. F.; but these variations do not alter the accuracy of my dose record, which is the difference between the minimum and maximum rheostat-readings independent of the number of cells it takes to furnish the given inductive force."

56. Doctor Monell further states: "The difference, also, in power to penetrate tissue-resistance will create a different zero-point for each length and size of wire, even with the same E. M. F., inducing force, and same electrodes; but, with standard coils, a standard method of finding the actual zero-point in all cases, with any coil, with any number of battery-cells, and at any period of their life, my method furnishes a flexible, permanent, and accurate measurement of the true therapeutic dose. Its adaptability to varying conditions of current-volume, voltage, resistance, and density removes all sources of error."

HYDRO-ELECTRIC METHODS.

ELECTRIC BATHS

57. Localization.—"*L'electrisation localisee*," the famous beacon-light of Duchenne, is fast fading from view. Treat the patient locally if you must, but treat him constitutionally in any case, seems to be the watchword of modern electrotherapeutics. It is not intended to detract one iota from the easily observed therapeutic powers of electricity locally applied, but

rather to assert that localized electrization no longer occupies the throne upon which the genius of Duchenne placed it. After static methods, as a means of general electrification, the electric bath stands first in importance. To administer the electric bath with benefit and without danger, the electric conditions must be carefully studied and thoroughly understood. Other means of general electrification are much employed, and their technique will receive attention further on. No one today questions the powerful, invigorating, and refreshing action of the electric bath. Centuries ago, animal electricity was utilized in this manner to combat the evil effects of rheumatism, scrofula, and various cachexiæ. Time has only served to increase confidence in its curative powers, and each succeeding year witnesses some new extension in the field of its practical utility. With a few elementary principles well fixed in the mind, with a clear knowledge of the physiological action of the different currents on the human system, with the electrical conditions surrounding an electric bath throroughly mastered, nothing can be more convenient and free from *contre temps* than the administration of an electric bath. The first points to study are the structure of the bath and the means of charging its contents with electricity. The best materials for constructing a bath for electric purposes are wood and porcelain—porcelain is for various reasons to be preferred. If made of metal, the electricity will travel along the metal, instead of through the patient and through the water. For the same reason, the fewer electrodes attached to the bath the better, because they simply serve to attract the current from the patient. The bath must be effectively insulated; it must not be in metallic connection with the earth. The waste-pipe can be connected to the bath by 4 or 5 inches of rubber tubing. The faucets supplying hot and cold water are not directly connected with the bath, and may be placed 4 or 5 inches above its margin.

58. Insulation.—With a current of moderate amperage and low electromotive force, insulation is not necessary. When, however, one desires to make use of all the therapeutic properties of the electric bath, insulation becomes a necessity.

Complete insulation is not only possible but very easily attained. The porcelain bath is placed on four insulating supports. These may be made of either glass or vulcanite. The faucets for hot and cold water must have no connection with the bath, and are placed 4 or 5 inches above its margin. The bath is emptied by siphon action into a sink, which is placed close by. A bath

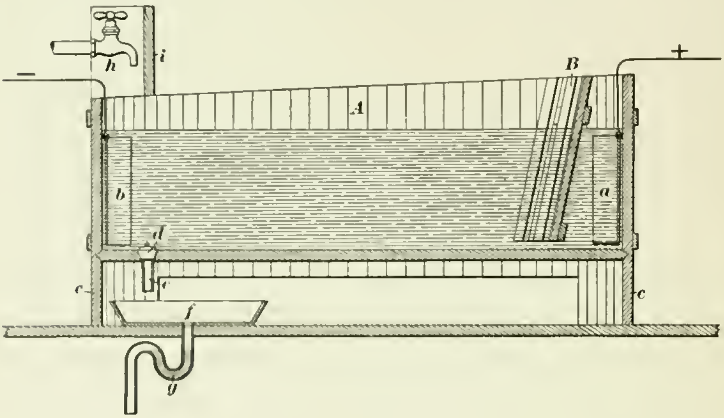

FIG. 1.

thus constructed and located is in no danger of establishing electrical connection with the earth. Fig. 1 illustrates this form of bath. For description see Art. **110**, page 84, section 4.

MONOPOLAR AND DIPOLAR BATHS.

59. The Monopolar Bath.—Electric baths are of two kinds, viz., monopolar and dipolar. In the monopolar bath, one electrode is applied to the nape of the neck or to the arm or to some part of the body out of the water. The water of the bath constitutes the other electrode, and very accurately adapts itself to all parts of the submerged body. If the electrode applied to the body outside of the water is made positive, the current will then flow from the electrode into the body. It is therefore evident that in the monopolar bath the whole current employed must pass into the body. The copper electrode, to which a stout rheophore is attached and placed at the foot of the bath,

completes the circuit. Part of the current diffuses into the water from all parts of the body, to be again concentrated in the foot-electrode, whence it flows to the negative binding-post. The disadvantage of this form of bath is that only moderate currents can be employed, as the electrode applied outside of the water is, of necessity, small. If the current is strong and too concentrated, it would cause pain and produce destructive local electrolytic action.

60. The Dipolar Bath.—The dipolar bath is the one habitually used in practice. It must be completely insulated, and is supplied with two electrodes usually made of copper. It is useless to plate the electrodes for purposes of appearance, because the current will quickly transfer the plating from the positive to the negative electrode. The electrode at the head of the bath is usually the larger, and measures 18 in. × 12 in. The electrode at the foot of the bath measures 11 in. × 9 in. The shoulders of the patient must be protected from contact with the head-electrode, in order to prevent burning and pain. This is accomplished by placing a wooden framework between the shoulders and the electrode. The wooden framework is illustrated in Fig. 1. The soles of the feet, on account of their poor conductivity, may be placed against the foot-electrode.

Another subdivision of electrical baths is made by the physical qualities of the current employed. The electrical bath may be of the continuous-current type or it may be the alternating; if alternating, it is either a symmetrical or a dissymmetrical current. The dissymmetrical current is obtained from the medical faradic battery. The symmetrical, or sinusoidal, current is obtained from a therapeutic alternator. The direct current may be either steady or pulsatory. The steady current is obtained from the medical galvanic battery. The pulsatory current is obtained from a dynamo. The direct current may be interrupted at the will of the physician. In employing either the direct or the alternating current, a good rheostat should be in circuit, so that the current can be under the control of the physician. By means of the rheostat, the current can

be gradually turned on, and when the séance is completed, can be turned off with the same care.

61. Function of the Rheostat.—The rheostat protects the patient against any shock that might be caused by turning the current on or off too quickly. It further enables the physician to control the sensation produced by the current, whether direct or alternating. In using the galvanic current, a milliammeter and a rheostat are both necessary, and should be employed in every administration of the galvanic bath. It is always important to turn the current on slowly, and carefully observe the effects produced on the patient. During the entire administration of an electric bath, the physician should be in the room, and carefully note the effects produced on the nervous and circulatory systems. The pulse and respiration should be counted and carefully watched during the administration.

62. Available Current.—A question that continually presents itself is, What part of the total current passing through the water of the bath passes through the patient? The question is for obvious reasons of the utmost importance. It has been very carefully and minutely examined by Hedley, Jones, Meylan, and others. The question is best studied by regarding the patient and the water as parallel branches of a divided circuit. Looking at the question in this way, it will be easily understood that the amount of electricity passing through the patient will depend on the relative resistances of the patient and the water. The amount of electricity passing through the patient is today accepted as being about 25 per cent. of the total current. This is given as the average current-strength, and not as the maximum. Thus, if the milliammeter registers 150 milliamperes, the patient is subjected to a current of about 25 milliamperes. Steavenson and Jones give about 20 per cent. of the total current as the amount passing through the patient. It may again be repeated that the current should always be gradually turned on by the physician himself, and the effects produced on the patient carefully observed. Both electrodes should be covered by the water in the bath, and the

whole of the patient's body, with the exception of his head, is also completely immersed in the water.

63. Temperature.—The temperature of the water is also a question of importance, as the higher the temperature the better its conducting capacity. The more current passing through the water, the less will pass through the body. When the physician can command any current-strength desired, the temperature of the water makes little difference, because it is only necessary to increase the strength of the total current to obtain the required current for the body. The usual temperature of the bath is about 98° F. It is, however, regulated to suit the conditions of the patient. The custom of adding salts or acids to electric baths is to be condemned, particularly when the physician is using a current from Leclanché cells. The salts and acids increase the conducting capacity of the water, and lessen the current-strength passing through the patient. Further, allowing for the therapeutic action of the electric current, the effect of acids and salts in baths is extremely problematical. The usual rule of not taking a bath immediately after a full meal holds also in the case of electric baths. The effects produced by an electric bath are usually exhilarating and refreshing. The patient feels invigorated after the bath, and there is no tendency to take cold.

64. Current-Density.—On account of the large sectional area of the composite conductor in the case of an electric bath, and further, on account of the difference of resistance between the water and the patient, current-density assumes special importance in the administration of electric baths. Of course, current-density is just as important in other electrical applications as it is in the electric bath, but the prejudice existing against electric baths makes it necessary to state plainly and squarely everything connected with them. The electric current flowing through water in a bath or through the human body between the electrodes or along the metallic conductor or in any circuit has been very aptly compared to a girl's hair, "which may be gathered up into a narrow tress or allowed to flow loosely, without changing the number of the constituent

parts." Whether flowing loosely or gathered into a narrow tress, the number of hairs remains the same. In the same way, the electric current may be conceived to be composed of a number of lines, which are near together or far apart, according to the current-strength and the sectional area of the conductor through which it is passing. The number of lines of current-strength remains the same whether the current is flowing through a narrow nerve or a piece of muscle of large sectional area. This is very clearly illustrated in Fig. 2.

THE ELECTRIC DOUCHE.

65. Method of Procedure.—In giving an electric douche, the indifferent electrode is placed under the patient's feet, or, if it is desired that the patient be seated, a gluteal electrode is used. The water coming from the rose, or nozzle, constitutes the other electrode, or the active electrode. This is in many cases a very agreeable and very efficient method of electric treatment. One terminal of the battery is connected with the electrode beneath the feet, and the other is attached to the insulated metal terminal of the nozzle, or rose. The electric douche combines the therapeutic properties of the hydriatic douche with those of general and local electrization. The treatment given with any form of current may be either local or general. The water coming from the nozzle renders the skin a better conductor of electricity, and at the same time increases cutaneous irritability, rendering the stimulating action of electricity on the periphery stronger and more effective. The induction-coil currents are very readily applied by means of the douche, and a current-strength perceptible to the patient is easily obtained. With one electrode placed under the feet or under the gluteal region, and connected with one binding-post of the battery or source of supply used, and the other electrode,

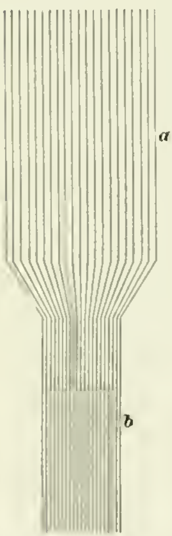

Fig. 2.

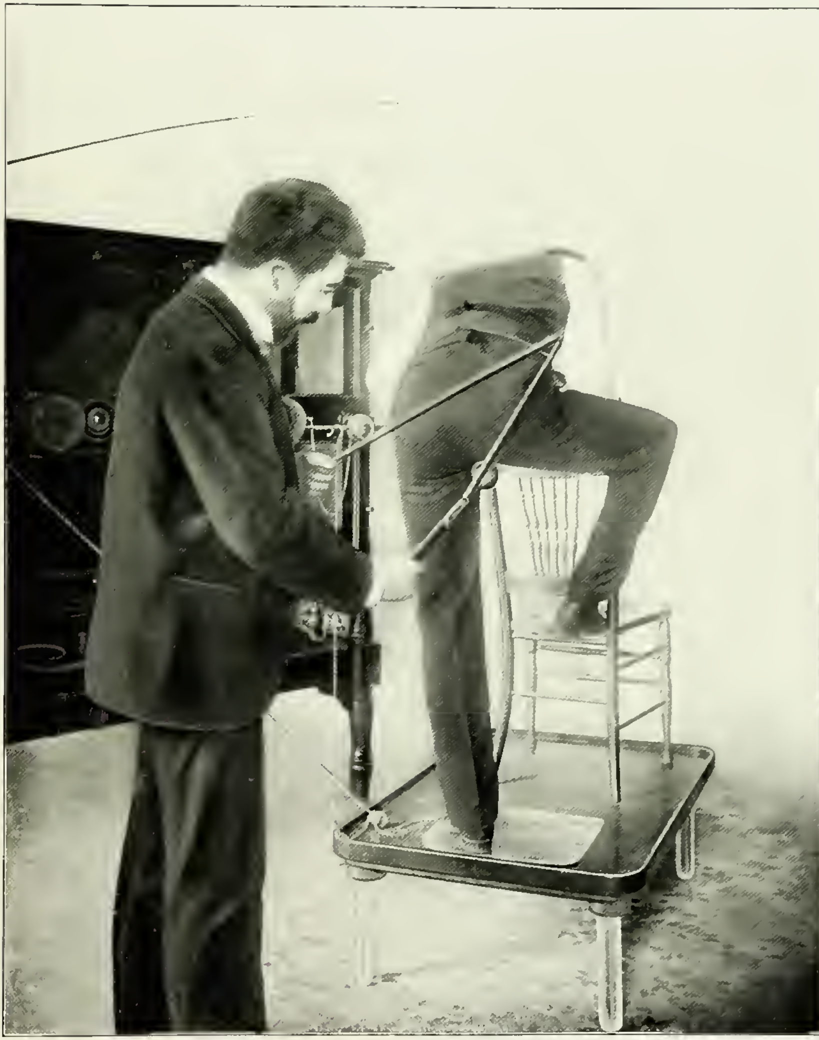

PLATE XIX.
Frictional Sparks to Perineum.

which in this case is the unbroken stream of water, connected with the other binding-post of the source of supply, the electricity passes through the water-electrode to the patient's body. The metallic nozzle, or rose, is insulated, and is not brought in contact with the patient's body. The unbroken stream or streams of water form part of the conducting current, and convey the electric current to or from the patient's body. In this way the electric douche differs materially from the electric vapor or the electric hot-air bath. In these last two electric methods, two electrodes are brought into direct contact with the patient's body. The hot air or vapor does not convey the electric current to the body. They both cause perspiration and heat the skin, and in this way facilitate the action of the electric currents. The indifferent electrode is placed under the patient's feet, and the active electrode on any part of the body the physician desires to treat. Two covered metallic electrodes are used in the electric hot-air or vapor bath.

66. Water as an Agency.—That water conducts electricity is a well-known fact. The douche may be electrized and the current conveyed to the patient as long as the stream of water remains unbroken. The douche may be composed of a single unbroken stream of water, or a number of streams may be projected from a rose. An unbroken stream of water and high electromotive force are necessary in this method of electrical application. In the electric bath no effort is made to increase the conductivity of the water; in fact, it is often a distinct advantage to diminish the conductive capacity of the water, in order to increase the current-strength passing through the patient. With the electric douche the opposite exists, and the aim is to bring all the current one can to the patient's body. The stream of water forming the douche is part of the electric current, and it should be made as good a conductor as possible. The conductivity of water is increased by elevating its temperature, and also by the addition of some salt or acid. The nozzle, or rose, is held at a distance from the body, which permits the water-pressure to deliver to the patient an unbroken stream.

67. Hot-Air and Vapor Bath.—The electric hot-air and vapor bath combine the effects produced by Turkish and Russian baths with the known therapeutic qualities of the current of electricity employed. The vapor-bath produces copious perspiration; the surface of the body is bathed in moisture and sweat, all the glands of the skin are stimulated to increased action, there is marked cutaneous hyperemia, and the body is rendered a very active electrolyte. The electric vapor-bath is given at a temperature varying from 90° to 105° F. The hot-air bath is well borne at a much higher temperature, varying from 100° to 120° F.

68. Summary of Hydro-Electric Methods.—The hydro-electric methods thus far studied are three, namely:

1. *The Electric Bath, Monopolar and Dipolar.*—Either of these is again subdivided by the physical qualities of the current employed. The currents employed are the galvanic current, which may be continuous or interrupted, and the induced current, which may be symmetrical or dissymmetrical. The symmetrical, or sinusoidal, current has invaded, within recent years, those domains of pathology that were once regarded as the exclusive field for the employment of the direct galvanic current.

2. *The Electric Hot-Air and Vapor Bath.*—From these two methods of applying electricity, the therapeutic effects of Russian and Turkish baths are added to the physiological properties of the various currents acting under the best conditions for their administration. Hot air and vapor do not conduct electric currents, but they do diminish cutaneous resistance and facilitate the penetration of electric currents into the body. Besides the effects produced by the electric currents used, the patient receives the benefit of the hydriatic and thermal properties of Turkish and Russian baths.

3. *The Electric Douche and Spray.*—In this form of treatment, the stream or streams of water constitutes the active electrode and conveys the electric current to the patient. It is a form of treatment adapted to a large number of pathological conditions, on account of the active manner in which it

produces peripheral stimulation. The douche alone has long been recognizca as an efficient tonic, alterative, and absorbent. These valuable therapeutic properties are simply augmented in efficacy by the judicious selection or combination with electric currents.

69. Treatment of Cavities. — Another method of hydro-electric treatment, which has been introduced into electrotherapeutics within recent years by Boudet, of Paris, has given to the physician a much needed means of combating and curing certain common and obstinate maladies. By this method is meant the hydro-electric douche applied to the mucous cavities and the mucous canals of the body. This method of treatment was quickly utilized in this country, and much of the knowledge of its therapeutic capabilities is due to the labor and writings of Dr. M. Cleaves. The dangers and

FIG. 3.
RECTAL ELECTRODE

difficulties of applying strong galvanic currents to mucous canals and cavities prevented the use of currents of sufficient strength to obtain desired results. These dangers and difficulties are now obviated by the use of special electrodes completely insulated and perforated to allow the passage through them of a current of water. The electrodes used simply convey the water and electricity; the water within the canal or cavity constitutes the true electrode. By means of a special electrode, illustrated in Fig. 3, direct galvanic currents of 20 or 30 milliamperes can be employed within the rectum without any danger of destructive electrolytic action. The electrode is inserted well within the bowels, and the water allowed to flow until the rectum becomes filled. The electric current is turned on simultaneously with the flow of water. The water in the bowels constitutes the electrode, and diffuses the current to all parts of the rectum.

This powerfully stimulates the peristaltic action of the intestines, and is one of the most efficient means of treating chronic constipation and the various affections involving the mucous and muscular layers of the large and small intestines. Alternating currents cause non-striated muscle-fibers to contract when they are not pathologically altered. It has been proved by direct experiment that non-striated muscle-fibers, when in a paretic condition, such as obtains in intestinal obstruction, respond little if at all to alternating currents, while vigorous contraction can be produced by the galvanic current. Celiotomy should never be performed for intestinal obstruction until the physician has made at least two thorough trials, separated by an interval of 3 or 4 hours, of the direct galvanic current applied by a special rectal electrode. During each séance two or three voltaic alternatives should be practiced. Cases have been reported by well-known observers, where surgeons were ready to open the abdomen for intestinal obstruction, in which one séance of galvanization, applied as directed above, with a few voltaic alternatives, produced in a short time a copious fecal evacuation. The rationale of the galvanic current in effecting a cure in these often deplorable cases is easily comprehended, and in presence of a case of intestinal obstruction should never be forgotten.

70. Treatment of the Rectal Mucosa.—Inflammation and ulceration of the rectal mucosa are simply and speedily cured by the hydro-electric douche. The electrode used is very simple, and the technique easily carried out in the physician's office, when a toilet-room is within convenient distance. If the hydro-electric douche had no other use than in the treatment of chronic constipation, its technique should be familiar to every physician. Cases of constipation, due to atony of the bowels and diminished glandular secretion, are more speedily and scientifically cured by the hydro-electric douche than by any other known remedial agent. To the water used it is always necessary to add 1 per cent. of common salt. Medicated solutions of copper, zinc, or silver may also be employed in this manner. These various salts in solution are driven into the

mucosa by the cataphoric action of the constant current. In the accompanying illustration, Fig. 4, is shown a vaginal electrode invented by Dr. M. Cleaves, and which is much used in treating pathological conditions of the vagina, uterus, and other pelvic organs. The electrode, through a canal in the center, conveys the water and also the electric current. The vulcanized disk prevents the escape of water until the vagina is completely distended. A current of from 20 to 40 milliamperes is generally used. It is easily seen that, with the vagina well distended, the electric current comes in contact with the entire vaginal mucosa and diffuses itself through all the pelvic organs, healthy or diseased. The vaginal electric douche is of real value in the

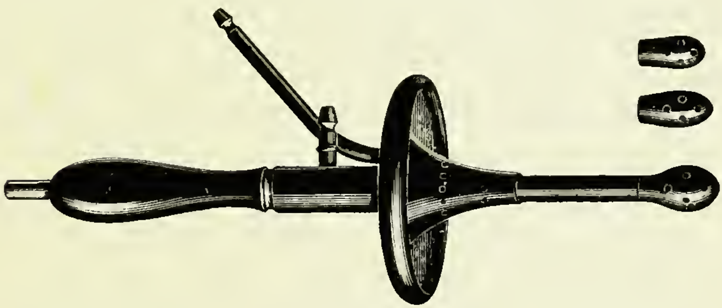

FIG. 4.
VAGINAL ELECTRODE.

treatment of vaginal, uterine, and ovarian troubles. The treatment causes no pain, and is rather agreeable than otherwise. Of course, the current must be gradually turned on through a rheostat and turned off with the same care. It constitutes a safe means of beginning electric treatment in the gynecological diseases of debilitated and nervous patients. Inflammatory affections of the uterine canal, ulceration of the os tincae, relaxed vaginal walls, and weakened pelvic structures in general, are very conveniently treated by the vaginal electric douche. The temperature of the douche is regulated to suit the sensations of the patient.

71. Interior of the Bladder.—The accompanying illustrations, Figs. 5 and 6, show electrodes for administering the galvanic current to the interior of the bladder. Fig. 5 is for the

male bladder, and Fig. 6 for the female bladder. For a long time the induced current has proved itself a valuable agent in treating paretic and nervous affections of the bladder, but it is

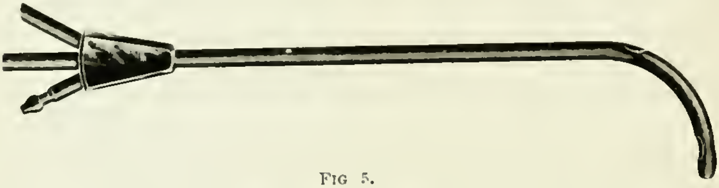

FIG 5.
MALE VESICAL ELECTRODE.

only lately that the galvanic current could be employed in sufficient strength to be efficacious. From 20 to 30 milliamperes are used in the interior of the bladder. Very good

FIG 6.
FEMALE VESICAL ELECTRODE.

results are obtained in chronic inflammatory conditions, with thickening of the mucous lining, accompanied by glandular atrophy. Vesical weakness and atrophy are much benefited by the direct current applied by means of the vesical douche.

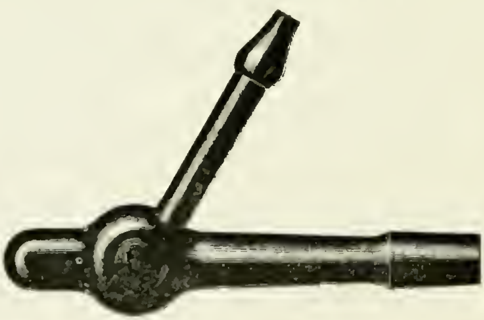

FIG 7.
NASAL AND AURAL ELECTRODE.

Catarrhal diseases of the nose and nasopharynx are much relieved or entirely cured by the electric douche. In atrophic nasal catarrh, the diseased glands are soon modified in their

function, and the nutrition of the mucous membrane is improved by each treatment. It is found serviceable, in catarrhal troubles of the nose, to add various medicaments to the water used. Among these, cupric sulfate is perhaps the best. Cases of atrophic catarrh of nose and throat have been reported cured, with complete return of the sensation of smell. For treating

FIG. 8.
POST-NASAL.

nasal and aural affections, the electrodes illustrated in Figs. 7 and 8 are used. The conducting material of the electrode is metal, well insulated with gutta-percha. From 3 to 10 milliamperes are used, and the séance lasts long enough to pass about 3 pints of water through the nasal cavities.

PHYSIOLOGICAL EFFECT OF ELECTRIC BATHS.

72. The Water-Bath.—Any study of the properties of electric baths involves a sharp distinction between the purely thermal effects produced and those properly belonging to the special form of current that the physician may see fit to use. The water-bath, at a temperature ranging from 95° to 105° F., increases the circulation and retards tissue metamorphosis. It is calming in all febrile conditions, and produces sedation in irritable constitutions when all symptoms of fever are absent. An increased amount of blood is brought to the surface of the body; internal organs are relieved of congestion, and are permitted to perform their functions under more nearly normal conditions. The cutaneous glands are slightly stimulated, and eliminate from the system increased quantities of effete material. The action of the hot-air, or Turkish, bath and the vapor, or Russian, bath is much more emphatic, and has a wide field of utility in various morbid processes.

73. Effect of Electric Baths.—The physiological effect of the electric bath may be summed up as follows: Respiration

is diminished by dipolar; the temperature is slightly lowered by monopolar; metabolism is promoted considerably by dipolar, slightly by monopolar; and the secretion of urine is increased. The appetite and digestion are improved, the genital functions are stimulated, circulation and nutrition are benefited, sleep is notably restored, and new vigor is imparted to the mental and physical faculties. In short, the electric, and especially the farado-electric, bath is credited by all with a powerful, invigorating, and refreshing action on the human frame. When a course of baths is given for tonic effects, the interrupted currents will give the best results. If cataphoric and electrolytic effects are desired, the continuous-current bath is used.

74. Gout, Rheumatism, Etc.—Gout, rheumatism, lumbago, and sciatica have been successfully treated by both currents. If the alternating current causes pain, the direct current should be employed. In disorders of the circulation, among which Raynaud's disease may be mentioned, the electric bath, local or general, is the best known treament. Weak currents are used to build up the nutrition of the parts diseased. Good results are obtained in Raynaud's disease, even after gangrene has supervened. The negative pole is applied over the diseased area, and the positive pole on some indifferent part of the body. The object of treatment is to increase the circulation in the diseased member. Weak galvanic currents serve the purpose best. In the local form of bath, the hand or foot affected is placed in a mild saline solution, which then becomes the active electrode, the indifferent electrode being placed on the spine. The galvanic current promotes absorption, accelerates the sluggish circulation, and increases the nutrition of the diseased member. The same results are accomplished in the general electric bath.

75. Rickets.—Very good results have been reported from Italy by Sagretti and Tederchi in the treatment of rickets by the electric bath. They ascribe the rationale of the treatment to the nutritive effects of the bath. Steavenson and

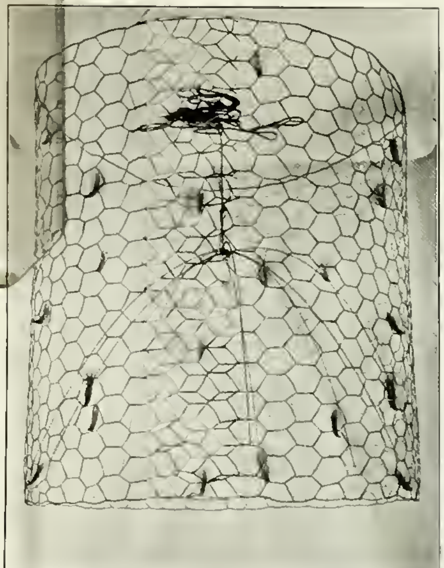

FIG. 1.
Static Cage.

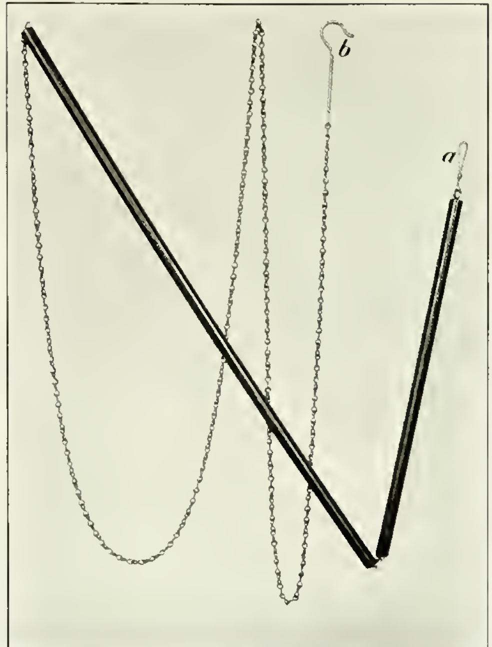

FIG. 2.
Dr. Monell's Insulated Electrode Handler.

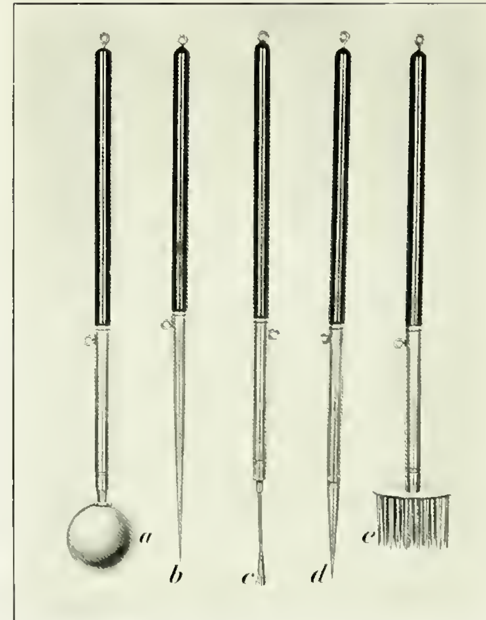

FIG. 3.
Static Electrodes.

PLATE XX.

Jones have also obtained striking results in the treatment of the same disease. After a few applications the general appearance of the patients is changed for the better: appetite and digestion improve, and the little invalids, from a condition almost bordering on spinal paralysis, regain rapidly the power of locomotion.

76. Anemia and Chlorosis.—The electric bath will often render good service as a general tonic and sedative in the course of treatment of anemia and chlorosis. True, these diseases are most conveniently treated by iron, arsenic, and purgatives, but it is well to know that the action of these valuable agents may be rendered more effective by the judicious use of electric baths.

77. Demedication.—The direct current has been used in bath form in the treatment of gout in the belief that biurate of sodium, through electrolytic action, was removed from the body. During the passage of every galvanic current through the tissues there is always electrolytic action, but this does not signify that biurate of sodium is eliminated from the body. In gout, the direct current does good by building up the tissues and increasing the tone of the nervous system. The alternating current acts as a general tonic. The direct-current bath has been used to remove mercury, lead, and silver from tissues impregnated with them, but with no success. Althaus reports a case of argyria, in which electric baths were persevered in for some time with absolutely no results on the stained tissues. Mercury has been found on the negative electrode of the bath when treating patients that had just gone through a course of mercurial inunctions for syphilis. It is most likely that the mercury came from the surface of the patient's body.

The subject of demedication has not received much scientific attention since the communication of Poey to the French Academy in 1855. No practical results have been obtained since this date, and the question is still *sub judice*.

78. Medicated Solutions.—If it has not been possible to remove various medicaments from the body by the cataphoric

action of the direct current, medicines dissolved in a bath have been made to penetrate into the system, where they exercised their therapeutic qualities. Syphilis, gout, and other maladies have been treated and benefited in this manner. Chronic rheumatism, rheumatoid arthritis, gout, and diabetes are four diseases for which a judicious selection of currents and proper attention to detail in a course of electric baths will accomplish more than massage, medicaments, change of climate, or all of them combined. When the joints are painful and swollen, the galvanic current is the one indicated. As a general tonic to promote elimination and give tone to the nervous and muscular systems, the interrupted-current bath is the best. The electric vapor-bath is indicated in plethoric subjects, where elimination of effete material requires special attention. On account of its tonic and invigorating properties, the interrupted current should be administered with the vapor-bath.

79. Symmetrical Alternating Current.—The symmetrical alternating current employed in the bath has given very good results in various diseases treated by Gautier and Larat. Among the diseases treated by them were "lymphatism," obesity, eczema, and diabetes. As might be expected, the hydriatic and electric properties of the bath are much used in the treatment of diseases of the nervous system. Neurasthenia will yield to a course of electric baths, when central galvanism and static methods have failed. Diphtheritic and other forms of toxic neuritis are conveniently and effectively treated in the electric bath. Weak mental states following exhaustive maladies from any cause, such as influenza, typhoid, and malarial fevers, begin to improve after the second or third application.

80. Summary.—In summing up, it may be said that the electric bath, water, vapor, or hot air, finds its greatest field of usefulness in depressed and irritable conditions of the nervous system and in diseases characterized by perverted nutrition. Chronic rheumatism, rheumatoid arthritis, and diabetes are common diseases, in the treatment of which

electricity is worth more than all other remedies combined. Among the different methods of applying the various currents in the treatment of those diseases, it is not easy to assign a fixed place to the electric bath. The physician, to obtain the best results, must have a clear conception of the properties of the water-bath, the hot-air bath, and the vapor-bath. With these properties well fixed in his mind, the further treatment of the case calls for a judicious selection of the form of electricity required to combat the symptoms of the disease to be treated. In the treatment of these diseases, whose march under the usual medicinal and mechanical treatment is steadily forward, galvanization, local or general, is frequently needed. Static methods render valuable service, and have a wider range of use than all other methods combined. In their turn, faradization, local and general, meet special indications, and will be employed by the physician when their known therapeutic properties are required.

81. Change of air, massage, tonics, alkalis, salicylates, and dietetic treatment are all faithfully tried by the physician in the treatment of these chronic and painful diseases. In chronic rheumatism and rheumatoid arthritis, after carefully applying the above-mentioned methods of treatment, the physician usually has, for all his trouble, a patient very much deformed, full of aches and pains, with little or no hope of ultimate recovery. It is conservative and within clinical testimony to state that the result in these diseases would be diametrically opposite had electricity been properly used in the beginning, and its use continued until the body gave every evidence of healthy functions. No one form of electricity will carry the patient all through the treatment of either chronic rheumatism or rheumatoid arthritis. The direct and alternating currents applied locally to combat special manifestations or generally to affect the entire system will also be found useful. Static methods cover a wide range of indications. Direct and alternating currents may be applied to the body either by the ordinary electrodes or by the bath—hot air, vapor, or water being used as electrodes.

GENERAL FARADIZATION.

82. Importance of General Faradization.—Electricity will take its proper place among remedial agents when the members of the medical profession know its therapeutic capabilities as well as they now know those of quinin, iron, and the mineral acids. With a little practice, the technique and the different methods of administering electricity can be easily mastered. The time required for each séance will be amply compensated for by the results, immediate and remote, of a proper course of electric treatment. General faradization has been much inveighed against on the score of its embarrassment to the patient, and the time and trouble to the physician. When the physician is in the presence of the indications for the employment of general faradization, and has faith born of experience in its powers as a curative agent, these complaints do not seem serious. Indeed, a careful survey of other curative agents, medical and surgical, excites surprise that any one could object to electric methods on account of the trouble in technique or the embarrassment of administration.

METHOD OF GENERAL FARADIZATION.

83. Essential Procedure.—General faradization may be given in the water-bath and in the hot-air bath or vapor-bath. It is most often administered by means of a large-sized metallic electrode covered with wash-leather. The operator may hold one electrode in his hand, and, with the other hand as an electrode, apply the current to the patient's body. This latter is a very effective method, and gives the physician complete control over the sensations produced by the current. In these different methods of general faradization, the negative electrode, made of copper, and of large size, is placed beneath the patient's feet or under the gluteal region, and the positive electrode is passed over the motor points of the body. The current should always be applied through a rheostat, and regulated to the tolerance of the patient. If the sponge electrode is used, it is well moistened with a solution of sodium

bicarbonate; and if its surface is well soaped, it will facilitate its movements over the surface of the body. It is not necessary to go over the entire body in administering general faradization. The head, cervical and abdominal sympathetic, also the entire length of spine, should receive special attention. Bony prominences are painful, and should be avoided. The first treatment is tentative, and the susceptibilities of the patient are noted, in order to regulate dosage of subsequent treatments. In applying faradization to the neck and head, the wet hand has many and decided advantages as an electrode. In using the hand, the sensations of the patient are under control, and the different motor points of the cervical region are much

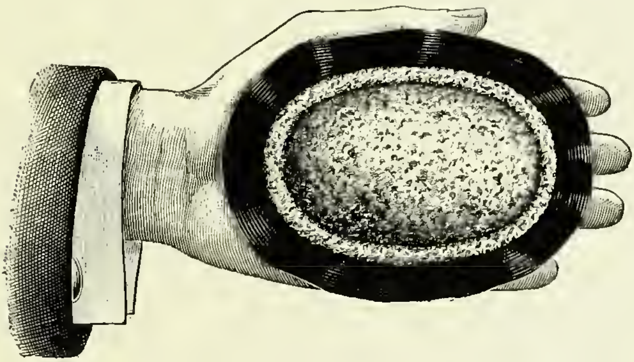

FIG. 9.

more easily reached and better acted on than could be done by any conceivable artificial electrode. The hand may be changed for the sponge-electrode (Fig. 9) when treating the spinal, thoracic, and abdominal regions. The lower extremities are usually sufficiently affected by the electrode applied to the soles of the feet. The upper extremities may be acted on through their nerves in the cervical region. On account of the physiological importance of the ciliospinal center, it should be given special attention in every general faradic treatment. The current employed does not affect the operator when he uses his hand as an electrode, except perhaps to produce slight fatigue. Indeed, it is rather beneficial to the operator than otherwise. Cases are

reported where the muscles of the arm gained in size and strength, due wholly to the use of the hand as an electrode. The use of the hand as an electrode should always be resorted to in applying faradization to the head and neck. The results obtained by the hand-electrode are much better and more agreeable to the patient than those produced by the sponge-electrode. That electricity should always be applied *in locus morbi*, as taught by Benedict, is true only in a limited number of diseases. Local diseases quickly alter the functions of the entire organism. Special attention is given to every local manifestation of disease, while general electrification is used to tone up the system, improve nutrition, and resist morbid processes.

84. Object of General Faradization.—The object of general faradization is to submit all parts of the body, particularly the motor points, to the influence of the faradic current. As a rule, the negative pole is applied to the soles of the feet or to the gluteal region, and the positive pole is applied to the various motor points of the body. If the operator desires it, the poles may be changed and the motor points submitted to the more stimulating properties of the negative pole. When applying the faradic current to important nerve-centers, a weak current is first used, and then gradually increased through the rheostat, to the toleration of the patient. By following this rule, the best results will be obtained when it is desirable to act on centers of special importance. In very feeble or paralytic patients, the negative electrode must be secured to the patient's feet, or placed beneath the coccyx. Young children are treated by placing a sponge-electrode beneath the coccyx, the physician using his own hand as an electrode. This is certainly the best method until the child becomes habituated to the sensations produced by the current.

85. Rhythmic Faradic Stimulus.—The experiments of Debedat, cited in Art. **20**, show very clearly the increased physiological development of muscles submitted to the rhythmic faradic stimulus of 30 interruptions per minute. The same

author proves with equal clearness that prolonged faradic tetanization causes physiological atrophy. The great utility of rhythmic faradic contractions, 30 per minute, when applied to all the muscles of the body, must appeal to the physician as one of the most valuable therapeutic agents at his command. Rapid interruptions, with high electromotive force, producing tetanus, if properly managed, will render the patient striking service, and exhibit, in an easily understood manner, the ability of the operator. If a motor point is submitted to tetanizing interruptions for a brief duration, fatigued and exhausted muscles are given a feeling of lightness and buoyancy. There is no increased physiological development, but the *bien être* of the patient is very much improved. A feeling of muscular weakness and exhaustion may be instantly relieved by a proper application of a rapidly interrupted current to the different motor points of the body.

A large number of patients coming to the physician's office for electrical treatment require an agent whose effects are tonic and stimulating. It is well known in electrotherapeutics that alternating currents possess these properties in the most striking manner. The physician should, therefore, have the therapeutic properties of these currents firmly fixed in his mind.

86. Important Considerations.—The following points should be carefully observed in every faradization, local or general, in the bath or with the usual electrodes.

1. The electromotive force employed, whether high or low.
2. The number of interruptions per minute, whether 30, 150, 2,000, or 10,000.
3. The character of interruptions, whether smooth and even, or irregular and "jerky."
4. The effects produced on the neuromuscular system, and the duration of the séance.

87. Many diseases are self-limited, and recovery may result without any treatment, sometimes in spite of treatment. This is also true when applied to electricity as it is used in medicine. The best results, however, will be obtained by the physician that has a thorough knowledge of the physiology and

therapeutics of the current he is about to use. Further, to secure success, he must know how to regulate electromotive force and to determine the required number of interruptions necessary in any given case, and to be able to properly time the length of the séance. The susceptibilities of the patient and the varying tolerance of different portions of the body will also require special study.

TECHNIQUE OF ELECTRICAL APPLICATIONS.

88. Application of Electricity to the Head.—When treating a patient by the method of general faradization, care must always be exercised in applying the current to the head. Bony surfaces are always painful to electric applications, and the head makes no exception to the rule. For the first few applications it will be safer for the physician if he grasp the negative electrode in his left hand and use his right hand as the positive electrode. By pressing more or less on the electrode held in his left hand, the strength of the current applied to the patient can be very closely regulated—can be increased or diminished at the will of the physician. The hand used as an electrode is kept thoroughly wet, so that in this manner current-strengths, trying to the physician, will be borne without complaint by the patient. When the hand is placed in the region of the cerebellum, the current-strength may be considerably increased, as this part of the cranium tolerates strong currents. When the hand is over the cerebellar region, and rapid interruptions with a high electromotive force are used, flashes of light and metallic taste are very frequently observed.

89. Application of Electricity to the Cranium. As dry hair is a non-conductor, some means must be taken to permit the electric current to reach the brain. In the case of females, moistening the cranial center, a point midway between the ears on the summit, will serve to pass a weak current and accomplish the effects desired. The cranial center is the most important center in electrical application to the head. In male patients, the whole head may be moistened with water and the resistance to the current reduced as much as

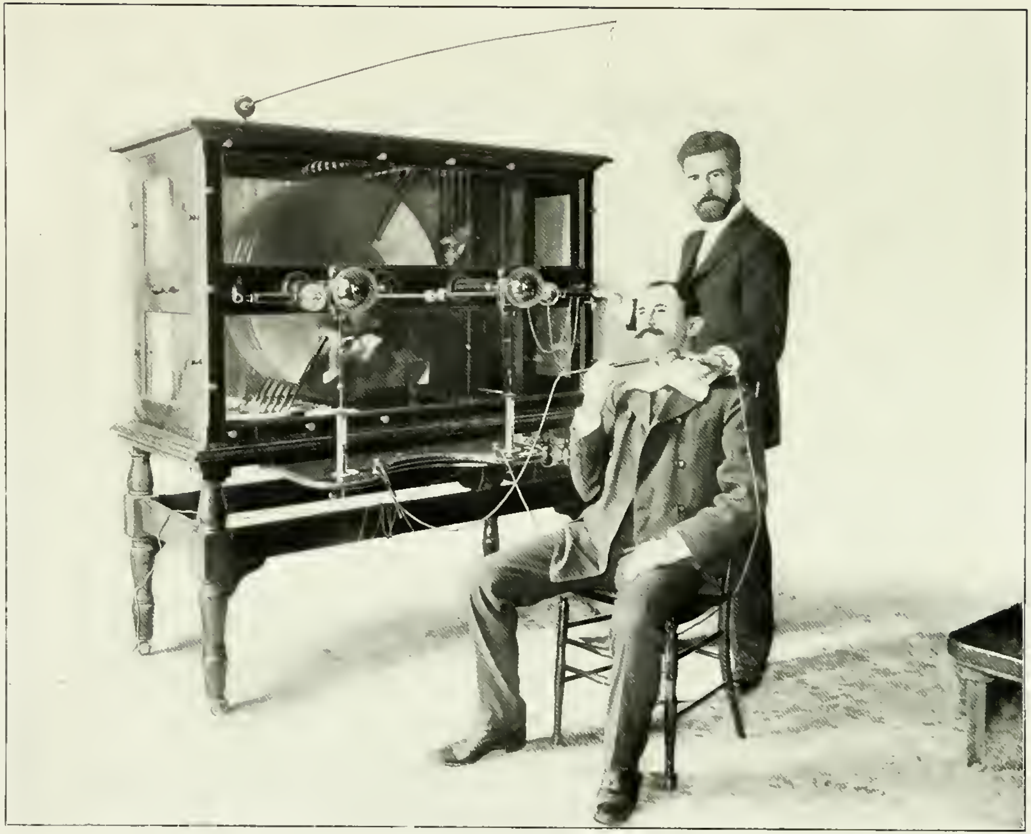

PLATE XXI.

possible. In applying faradization to the cranium, the fifth pair, the seventh pair, the cerebral centers, and the muscles of the cranial region are submitted to the influence of the faradic current. There is little, if any, electrolytic action produced, but marked tonic and stimulating effects follow each application. The nearer the alternating current approaches the sine-wave type, the less can electrolytic action occur. In well-marked dissymmetrical wave-currents, there must be some electrolytic action, and this should always be remembered in faradizing the cranium. In using electricity on any part of the body, the physician's intellect should be wholly occupied by the work he is doing; but this becomes emphatic and allows of no exception when electricity in any form is being applied to the region of the head. The application of electricity in any form to the cervical region is worthy of all the attention of which the physician is capable. Through the cervical region pass the pneumogastric and phrenic nerves, and the brachial plexuses; and close to the spinal column on either side is found the chain of sympathetic ganglia. All these important structures can be influenced in their functions by electric currents, particularly when the hand of the physician is used as an electrode. In enumerating the nerve structures of the neck, the large arterial trunks must not be forgotten. These latter, by appropriate manipulation with the hand-electrode, can be contracted or dilated at the will of the physician, and the cerebral circulation directly influenced.

90. Cervical Region.—It is well established in the physiology of electrotherapeutics that rapidly interrupted induction-coil currents increase the vermicular motion of the muscular layer of the arteries, and that when the electric current is flowing in the direction of the normal vermicular motion the flow of the blood-current is increased. When the electric current opposes the direction of the normal vermicular movement, the flow of the blood-current is diminished. In applying the rapidly interrupted current to the cervical region, as part of the treatment of general faradization, the physician has to some extent the circulation of the cerebrum under his control.

Faradization of the spine requires some practice to produce all the effects of which it is capable, and is remarkable for the number of phenomena that it induces. For example, with the sponge well moistened and firmly pressed over the ciliospinal center, the most important center of the spine, the lungs are influenced through the phrenic nerves; the larynx, through the laryngeal nerves; the stomach, through the pneumogastric nerves; and the superior members, through the brachial plexuses. The influence of the electric current, thus modifying the most vital parts of the nervous system, gives a sound physiological basis for its use in the cure of disease. During this application to the ciliospinal center, the sympathetic ganglia are also modified in their functions, and the wide range of their physiology is also utilized in directing and modifying pathological processes. To obtain the full benefits of faradization of the ciliospinal center, the sponge is well moistened and firmly pressed against the vertebræ. Strong currents must also be used.

91. Ciliospinal Center.—With the exception of the perineum, there is no other part of the body where so many nerves may be influenced by a stable application as the part known as the ciliospinal center. The application of alternating currents to the ciliospinal center is worthy of the most careful attention and painstaking care. Some patients, even with weak currents, are annoyed by a persistent cough, due to stimulation of the laryngeal nerves. Others complain of a feeling of depression, referred to the epigastric region. As a rule, however, the effects produced in all classes of patients are exhilarating, tonic, and sustaining, even from the first application. A proper application to the ciliospinal center is the most satisfactory part of general faradization. The patient usually demands its repetition, and expresses his sense of gratitude for the beneficial effects produced. In treating patients with a thick layer of adipose tissue, extra precautions must be taken to get the current to the center. The sponge should be well saturated in some saline solution, and firmly pressed against the spinous processes. The current is also increased in strength.

In fact, the current is turned on through the rheostat until the patient expresses a feeling of intolerance. Before beginning treatment the surface-area of the ciliospinal center is well moistened with water.

92. The Spine.—After attention has been given to the ciliospinal center, and all the effects produced of which the current used is capable, the application is continued along the entire length of the spine. The sponge is still firmly pressed to the spinous processes; but after the scapular

FIG. 10.

region is passed, the electrode may be applied to the hepatic, renal, and splenic regions, descending to the cauda equina, carefully avoiding the innominate bones. The middle portions of the spine tolerate strong currents, without the least expression of pain or annoyance. The electrode illustrated in Fig. 10 is often used in making applications to the spine.

93. Genitospinal Center. — Sufficiently trustworthy experiments have already accumulated to justify the assertion that the alternating current acts as effectively on the genitospinal center as it has been shown to do on the ciliospinal center. A study of the physiology of the genitospinal center before an electric application, compared with a study made after an electric séance, leaves no room for doubt concerning the influence of electricity on this center. The skin must be well moistened, the electrodes thoroughly saturated, and the current-strength carried to the tolerance of the patient. Attention to the coil used, its vibrator, and its inducing E. M. F., with a knowledge of the susceptibilities of the patient, will contribute much to the results obtained.

These two centers, the ciliospinal and the genitospinal, are, through the testimony of clinical experience, the most important

parts to be attended to in general faradization. With a well-saturated electrode placed over either of these areas, and a strong current used, the phenomena produced are striking, and will always command the attention of the physician. When the cranium has been submitted to the action of the current, as described, and the anterior and posterior triangles of the cervical region carefully and appropriately acted on, the other two areas commanding attention in general faradization are the ciliospinal and genitospinal centers. It will thus be seen that in a properly conducted séance of general faradization, the entire neuromuscular system is submitted to the tonic stimulating influence of alternating currents. It cannot be made too clear that the results obtained will depend in a large measure on the skill of the operator, on the electromotive force employed, and on the rapidity and evenness of the vibrations. The vibrator ought to be easily and noiselessly manipulated, so that the patient will not become alarmed by any change in technique that the physician may see fit to make.

94. The Thoracic Region.—The organs of the thoracic cavity are little or not at all influenced in their functions by applying the electrodes to the thoracic walls. To influence the thoracic organs, the nerves supplying these organs must be acted on at a distance—in the spine or in the angles of the cervical region. Much good, however, can be accomplished by applying both electrodes to the thoracic walls, or the negative electrode to the feet or gluteal region, and the positive electrode moved over the surface of the thorax. With well-regulated interruptions, the external and internal intercostal muscles, with other muscles attached to the ribs, are increased in physiological development by every faradic application. On account of the anatomical formation of the chest, strong currents are not tolerated, yet currents of sufficient strength to increase physiological development are agreeable to the patient, and in the majority of cases are well borne. In some patients, the hepatic and splenic regions are unaccountably tender, and justify the suspicion that the important organs of these areas are more or less diseased. Faradization of the thoracic walls is

beneficial simply as a muscular stimulant; there is no action produced on the heart or lungs by direct application.

95. The Abdomen.—The anatomical conditions of the abdomen differ greatly from those of the thorax. The conditions of electric conduction are much better in the abdominal than in the thoracic region. The alternating current acts directly on all the organs contained in the abdominal cavity, without any regard to their nerve-supply. The skin is well moistened and the electrodes thoroughly saturated. Adipose tissue is a poor conductor of electricity, and this must be thought of and compensated for, in treating corpulent patients. In corpulent patients, the active electrode is made somewhat larger; it is thoroughly saturated and pressed on the abdominal viscera with as much force as the patient can comfortably bear. The action of alternating currents on non-striated muscle-fibers drops rapidly in diseased conditions, such as paresis, atony, etc., and the direct current is then used. In every application of general faradization, the abdominal viscera should receive a few minutes' attention, and the physician should be particular to bring the organs contained in the abdominal cavity under the influence of the alternating current. The treatment gives tone to the flaccid voluntary muscles at the same time that it stimulates the function and increases the nutrition of the deep-seated organs.

96. The Lower Extremities.—The anesthethic properties of the faradic current, and its important uses in gynecology, do not properly come under the head of general faradization. It has previously been stated that the negative copper plate applied to the soles of the feet causes sufficient electrical action on the lower extremities. If it becomes necessary to extend the application, the patient is requested to stand on the copper electrode while the physician goes over all the motor points of the lower extremities. In this method of application, the hand makes a very serviceable electrode. The tolerance of the external and internal surfaces of the thigh differs widely. There are very few sensory nerves distributed to the external part of the thigh, whereas the shower

of nerves known as the *anterior crural* renders the internal surface of the thigh very sensitive. The physician will best control the effects of the current by holding the negative electrode in his left hand and applying his right hand, well moistened, to the parts selected. By pressing on the electrode held in his left hand, the current-strength can be instantly increased or diminished. While making these applications, the superior part of the body should be well protected by clothing. The physician must always think of the comfort and convenience of his patient.

97. The Upper Extremities.—The upper extremities are usually sufficiently affected by the current when it is applied to the spine or cervical region. It may be necessary in certain cases for the physician to make direct application to the motor points of both arms. In doing this, the object to be attained is kept steadily in view. If tonic vasoconstrictor effects are desired, the interruptions are made rapid, and the electrode simply permitted to make contact, and no more. If physiological development is required in cases of paralysis, slow interruptions (30 per minute) are used, and the application is continued for about 5 minutes. To secure this rhythmic faradic interruption, 30 per minute, a special clockwork mechanism is required. This mechanism is a necessity, when physiological exercise of paretic or paralyzed muscles is the point in view. The ordinary battery is not arranged for giving accurately 30 interruptions per minute; and, as the rate of interruptions plays an important rôle in electrotherapeutics, the clockwork mechanism should be attached to the battery for effective work. A rapid rate of interruptions per minute rapidly fatigues the muscles, diseased or healthy, and will, in a short time, cause physiological atrophy, the exact opposite of that which the physician desires to secure.

98. The Hand as an Electrode.—In beginning a course of treatment by general faradization, if no contraindications exist, it is best to use the hand as an electrode. In this way it is possible to avoid shocking the patient or throwing

him off his feet in applying alternating currents to the lower extremities. There are certain objections to using the hand as an electrode—objections on the part of the physician, and objections on the part of the patient. In the presence of disease, however, and confronted with the desire to recover, the objections on both sides, one might think, could be easily overcome. Without doubt, when applying electricity to certain portions of the body—to the head, neck, or internal surface of the thighs—no artificial electrode yet constructed has the pliability or adaptability of the human hand. When the patient becomes habituated to the sensations of the current, or when the physician has the susceptibilities of his patient completely under control, the sponge-electrode may be employed, or the use of the hand-electrode continued. The electrode used will be determined by the individual opinion of the physician; yet the physician will never regret having used his hand as an electrode, at least for the first few applications, particularly when applying electricity to the head, neck, or inner surface of the thigh.

99. An Average Application.—The tonic stimulating effect of general faradization can be secured without acting directly on either the upper or the lower extremities. In the majority of cases a 1-minute application to the head will suffice, because it is more sensitive and responsive to the action of the current, and as a rule is not prolonged beyond this period. The neck, sympathetic ganglia, and cervical spine occupy the greater part of the séance; next come the back, abdomen, and, if necessary, the upper and lower extremities.

An average application may be apportioned as follows:

1. Head, 1 minute.
2. Cervical region, including the cervical spine, 5 minutes.
3. Entire length of spine, including hepatic, splenic, and renal regions, 4 minutes.
4. Anterior abdominal region, about the same time.
5. The time devoted to the upper and lower extremities will be determined by the judgment of the physician and the effects to be produced.

100. The Time Element.—The time necessary for all electrical applications varies but little. General faradization, central galvanization, and static methods all require about the same time. The treatments may be repeated daily, on alternate days, or once a week, according to the diseased condition. Even a faradic or galvanic application for a peripheral affection will be found to consume about the same time as general faradization or a required static application. In the language of Trousseau, "chronic diseases demand chronic treatment." A course of iron will have accomplished little at the expiration of one week. To obtain the full benefits of any ferruginous preparation, several months are necessary. The same is true of electricity given in any form; one or two séances will accomplish very little in the direction of complete cure. Most patients applying for electrical treatment have some chronic malady, and chronic maladies require chronic treatment. No matter what the case, at the end of one month there should be some improvement, and the improvement, however slight, will give encouragement to the patient and justify the physician in continuing his plan of treatment. Daily séances give the best results, and cases present themselves in which treatment twice or even three times daily will be found beneficial. The convenience of the patient and the judgment of the physician will determine the number of séances weekly. It will be well, however, to remember that two or three applications daily increase the efficacy of the treatment and inspire confidence.

RESULTS OF GENERAL FARADIZATION.

101. The results produced by general faradization are both primary and secondary. The primary effects are produced during and immediately after each application. The secondary effects occur one or two days after the application.

102. Primary Effects.—The primary effects of general faradization are very important. They are usually tonic and stimulating in their nature. A feeling of lightness, buoyancy, and *bien être* is the usual result when proper methods are

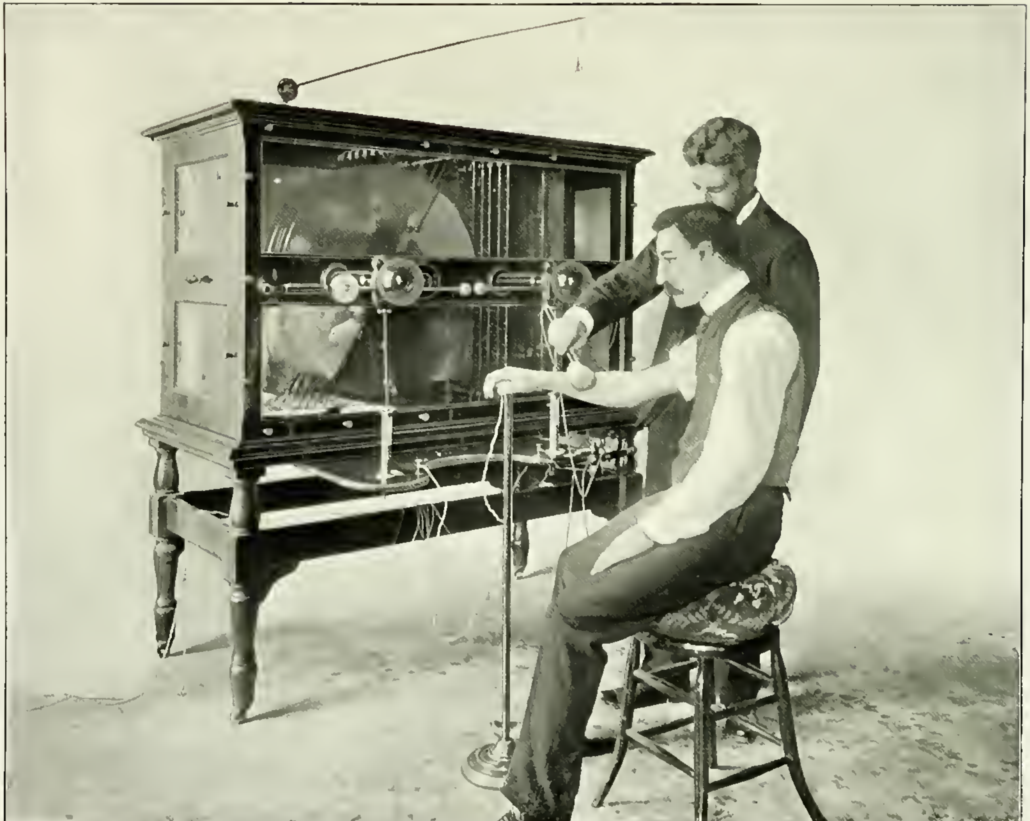

PLATE XXII

pursued. A sensation of malaise, depression, headache, lassitude, is not at all incompatible with permanent good results. The primary effects produced are largely controlled by the skill and manipulation of the operator. Patients, much dissatisfied with the first application, may return in a few days and express themselves very much improved. The relief of pain of various kinds and the feeling of lightness and buoyancy produced by the first application will usually inspire confidence.

103. Secondary Effects.—The feeling of soreness and fatigue so often complained of by patients submitted to general faradization can usually be avoided by making the first few applications tentative, and by using the hand as an electrode. Muscles that have not been used for some time, nerves semidormant for months, give a pathological reaction when submitted for the first time to the action of the current and awakened from their lethargy. In these cases use the hand as an electrode, make the séance short, or give massage in a mild form instead of electricity. Having once learned the endurance and constitution of the patient, the current-strength and the length of the séance may be increased. Annoying secondary effects are not likely to occur after the third or fourth séance.

The secondary effects occur after other methods of electric administration. Static sparks, vigorously administered, even to an apparently robust subject, will, after two or three days, cause muscular soreness and a general feeling of malaise. Changes in the physiology of the body are produced by an electric current that continue to act long after the current has been broken, or its contact with the body interrupted. The results of faradization may be apparent during the first séance; they may show themselves slowly during the course of treatment, or they may become manifest, for the first time, months after it has been discontinued. It may not be out of place to again state that, no matter what method is employed, some improvement should be manifest in one month; this will guide the future conduct of the physician. If no improvement takes place in one month, treatment may be discontinued.

104. Results Secured.—What results is a physician justified in predicting when he begins the use of coil-currents in the treatment of disease? First, last, and all the time, alternating currents are tonic and stimulating. They may be made sedative and paralyzing when improperly used, or when indications for sedative paralyzing effects present themselves. With the proper number of interruptions per minute, and the necessary electromotive force, the strength and nutrition of the entire muscular system are improved. This is a clinical fact that has been demonstrated in the laboratory. The experiments of Debedat establish this point beyond a doubt.

105. Insomnia.—Insomnia is a symptom common to many maladies. Sometimes static methods serve best; again, central galvanization has proved itself efficacious. In beginning treatment of this chronic and obstinate symptom, general faradization should never be forgotten. It increases the nutrition of brain and spinal cord, sends richer blood to a fatigued and exhausted stomach, increases the peristaltic action of the intestines, and relieves constipation. The entire muscular system, striated and non-striated, is increased in vigor, the physical forces of the human organism are harmonized, sleep is temporarily, and in the great majority of cases permanently, restored. Cases of chronic constipation are permanently cured after two or three months' treatment. The liver and spleen are acted on by alternating currents applied locally; and this action, added to the tonic stimulating influence on the splenic and hepatic nerves, establishes a *raison d'être* for the wide use of general faradization. Alternating currents may be made to exercise their specific action on the intrapelvic organs, in both the male and the female, without the use of an internal electrode. The effects produced on the organs contained in the pelvic cavity will depend on the electromotive force, and on the smoothness and number of interruptions.

106. Electrolysis and Chemical Action.—It is true that alternating currents, whether symmetrical or dissymmetrical, have no electrolytic action. At least they have no electrolytic action that needs the physician's attention.

Electrolysis in medicine and chemical action are synonymous, and the physician cannot think of one without explaining the other. Indirectly, then, the alternating current must possess decided electrolytic action. Surely, as has been demonstrated, it increases the strength, size, and nutrition of muscles; and the physician takes it that this is accomplished by increased chemical action. The circulation is increased in activity, interchange between the blood-stream and important viscera is accelerated, metabolism is augmented, elimination of used material is facilitated, and the entire organic physiology has new stamina imparted to it, which continues to act until opposing morbid forces establish an equilibrium.

107. "Modus Medendi" of General Faradization. So far as the physician is concerned, the *modus medendi* of general faradization has very little significance. The fact is that the cerebral and spinal ganglia are stimulated in their nutritive processes; whether this stimulation is due to increased supply of blood or whether the alternating currents act directly on these nerve-centers is not yet definitely determined. All through the physiology, technique, and therapy of alternating currents, tonic stimulating properties were always kept in view. Applied to the surface of the body, and acting on the terminal sensory nerves, this tonic stimulating property of alternating currents holds a very prominent place in the treatment of disease. It is well known that any impression—mechanical, chemical, thermal, or electrical—made on the terminal sensory nerves is carried to the central ganglia, where it is capable of modifying function or even producing organic changes. The wide surface covered by the positive electrode in general faradization must necessarily modify the function, and, if frequently repeated, changes the organic structure of the basic ganglia in a large section of the central nervous system. Of course, in hysteria and chorea and allied disorders, the object is to modify functions in central and spinal centers. But there are maladies in which the object most desired is organic change in the basic ganglia. Here, general faradization, properly applied and frequently repeated, will not prove disappointing.

108. Organic Lesions.—In spinal sclerosis, in cerebrospinal sclerosis, in locomotor ataxia, and in all nervous maladies with well-defined organic lesions, any agent capable of causing structural changes, if applied during the initial stage, should cure or at least arrest the pathological process. The same effects are obtained with static methods with less trouble, but many physicians that have not a static machine may be the owner of a good therapeutic induction-coil. The additional trouble in application is of little moment when the ultimate results to be obtained are kept in view. When counter-irritation and surface stimulation are desired, a dry brush-electrode is used. The physician wishes to produce, over an extended surface, the ordinary action of a capsicum plaster. This impress made by the peripheral electrical irritation travels along the sensory nerves to the centers in the spinal cord; it is then either reflected to some organ in direct nervous connection or it travels through the spinal column upward to the cerebral center. It then exerts its specific action on the cerebral center, and modifies functionally the organs in direct connection with these centers. The physiological stimulation thus initiated continues long after the current of electricity ceases to flow.

109. Permanency of Cure.—The permanency of a cure by electric methods has been widely discussed. A large proportion of cases treated by electricity, or that apply for electric treatment, must be classed among those that feel better one day and worse the next. In all these cases, a judicious selection of current, applied with proper care and *lege artis*, and for a sufficient length of time, will effect a permanent cure. After a course of electric treatment, even the most careful possible, relapses may occur. In this case, the course of treatment, more or less modified, should be continued until all symptoms of disease disappear. After any course of treatment—mechanical, surgical, or medicinal—relapses are liable to occur, and electric methods offer no exception to the general rule. The disease should be thoroughly studied before treatment is begun; the form of current appropriate to the pathological condition

carefully considered; and the dosage, the rate and character of vibrations, and the length of the séance, regulated to suit the symptoms and susceptibilities of the patient.

CENTRAL GALVANIZATION.

110. By this method of treatment, the brain, spinal cord, sympathetic ganglia, and pneumogastric nerves are brought under the influence of the direct current.

111. Mode of Procedure.—The negative electrode, of large size and well moistened, is placed over the epigastric region, and maintained there by the hand of the patient. The positive electrode is manipulated by the operator. The current-strength employed varies according to the susceptibilities of the patient. A good rheostat and milliammeter should always be in circuit. The entire séance usually lasts about 20 minutes. With the negative electrode firmly applied to the epigastrium, and the positive electrode to the central part of the forehead, the current is turned on through the rheostat. From 3 to 5 milliamperes are usually employed with the electrodes in this position. After 2 or 3 minutes, without breaking the circuit, the positive electrode is carefully moved to the vertex, where the current-strength may be gradually increased, the effects on the patient being carefully observed. The current-strength may be increased until the patient perceives a metallic taste. If this mode of procedure is not desirable, the current may be reduced to zero; the positive electrode is then lifted from the forehead, carried through the air, and placed on the vertex. The current is again turned on through the rheostat, but the patient will be able to support a much stronger current with the electrode on the vertex. After an application of 1 or 2 minutes to the vertex, the electrode is passed down the anterior border of the sternoclidomastoid muscle, the object being to influence the sympathetic ganglia and the pneumogastric nerves. Five minutes may be devoted to the sympathetic ganglia of the neck and the pneumogastric nerves. The application is

made to both sides of the neck. The next step in the treatment consists in applying the direct current to the entire length of the spine, special attention being given to the ciliospinal center. The technique of the entire treatment is very simple. The principal points to be attended to are the following:

1. The current is turned on gradually through the rheostat, and interruptions must be studiously avoided.
2. The effects produced on the brain, on the pulse, and on the respiration must be carefully observed by the physician.

The disastrous cases reported by Duchenne and Brown-Sequard are worthy of no more thought than those accidents that now and again happen in administering any medicament. Electricity, intelligently used, is as free from *contre temps* as any remedy in the pharmacopœia.

112. Difficulty in Technique.—There is very little difficulty in the technique of central galvanization when the physician is treating a male patient; and, indeed, when the indications for central galvanization are clearly defined, the same may be said for the technique of treatment in female patients. The trouble or embarrassment, or both, ascribed to the removal of corsets, is not worthy of serious consideration. The vertex or cranial center, the ciliospinal center, and the whole extent of the anterior border of the sternoclidomastoid muscles should receive special attention.

113. Current-Regulations.—The current is regulated through the rheostat, and the effects produced on the patient are closely studied. The current-strength tolerated in different cases varies from 3 to 30 milliamperes, according to the position of the positive electrode, the care with which the current is turned on through the rheostat, and the susceptibilities of the patient.

114. Manipulation of Electrodes.—When current-strengths above 2 milliamperes are used, the negative electrode, placed over the epigastrium, should be frequently moved, without breaking contact, in order to prevent local electrolytic action. The position of the positive electrode, whether on the central part of the forehead, the vertex, the parietal eminence,

or any other part of the cranial surface, will be determined by the disease treated and by the judgment of the physician.

115. Action on Cervical Sympathetic.—Whether the cervical sympathetic can be influenced by the direct current is still *sub judice.* Dr. de Watteville, in an article published in *The Brain*, denies any influence of the direct current on the cervical sympathetic.

116. The tendency of modern therapeutic writers is to accept the action of the direct current on the sympathetic, pneumogastric, and other nerves passing through the neck. Why there should be any doubt on this question is difficult to comprehend, because any physician can, by the proper position of the electrodes, and an appropriate current-strength, determine for himself, and always with the same results, the physiological and therapeutic action of the direct current when applied to the head or neck. The case described by Brown-Sequard leaves no doubt of the action of electricity on nerves traversing the cervical region.

117. Abstraction being made for all observations contributed for and against galvanization of the sympathetic, and remembering only the action, in general, of electricity on protoplasm, it is difficult to understand how a current that must of necessity traverse the entire thickness of the neck could do so without influencing, in some manner, the nerve structures found in the cervical region. It has long been taught in every textbook on human physiology that mild currents stimulate the movements of protoplasm, and that strong currents cause the cells to assume a spherical form and to become motionless.

RESULTS OF CENTRAL GALVANIZATION.

118. Action of Central Galvanization.—Central galvanization influences the brain, spinal cord, sympathetic ganglia, and pneumogastric nerves. The negative electrode is maintained stationary, being moved from time to time to avoid electrolytic action. The positive pole brings the various centers —the cranial, the ciliospinal, and sympathetic ganglia—under

the influence of the electric current. It thus embraces in its action the entire nervous system, and acts as a tonic, sedative or stimulating, according to dosage and manipulation. The active pole is usually made positive, because the indications for central galvanization usually call for tonic-sedative effects. Special indications may require that the active pole be made negative. Neurasthenia, insomnia, hypochondria, hysteria, and nervous dyspepsia are among the diseases most frequently treated by central galvanization, and the benefits obtained throw much light on the *methodus medendi* of the treatment.

119. This class of patients need a tonic-sedative treatment, and the invariability and rapidity with which they respond to central galvanization make it certain that this treatment has tonic-sedative qualities. Central galvanization is more than a local application of electricity to the cerebral centers, because one electrode is placed on the epigastrium and the other on the different parts of the surface of the cranium, including the entire length of the spine, the sympathetic ganglia of the neck, and the pneumogastric nerve.

120. Difference Between Local Galvanization and Central Galvanization.—In galvanization of the brain, the cerebral centers alone are acted on; one electrode is placed on either side of the head, or one on the forehead and the other on the occiput, and the current is passed directly through the cerebrum. The same is true in galvanization of the sympathetic. One electrode is placed in either auriculomaxillary fossa, and the current passed directly from one electrode to the other. In central galvanization, however, the cerebral centers, the spinal centers, the sympathetic ganglia, and the pneumogastric nerves are all submitted to the influence of the positive or negative pole at the option of the physician.

121. Indications for General Faradization.—When the indication is to build up the muscular system, to produce tonic stimulating effects, and to act reflexly on the central ganglia, general faradization is the proper treatment to apply.

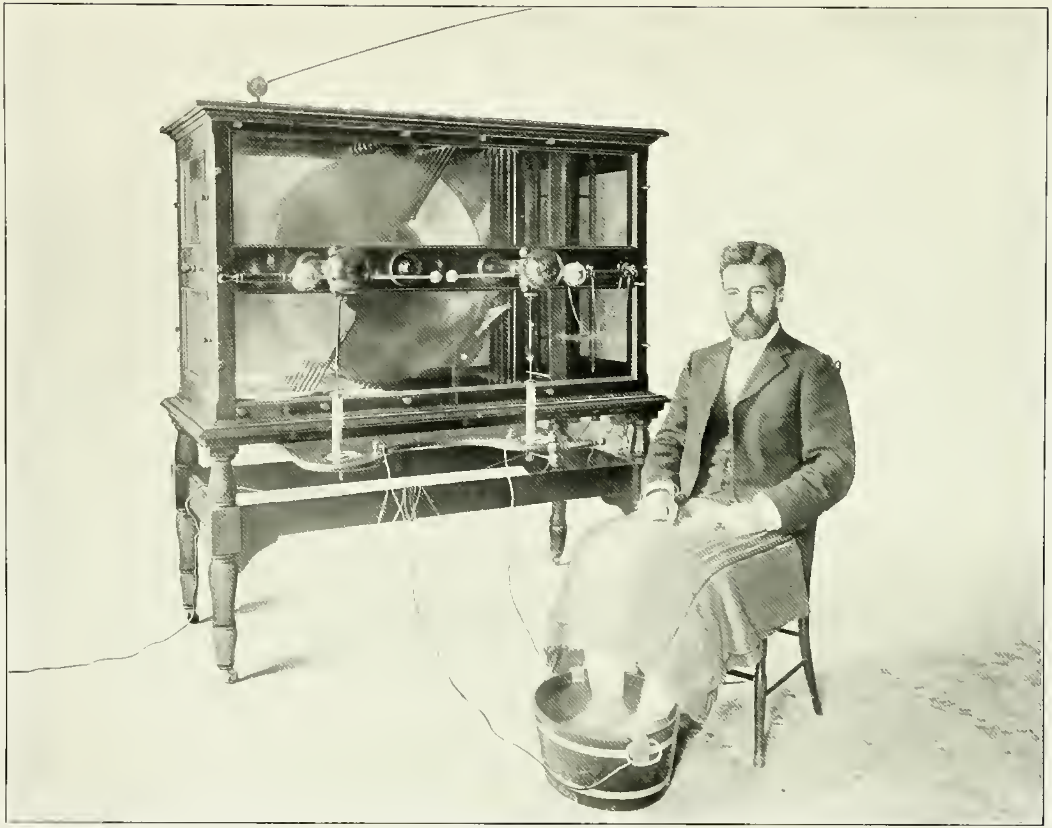

PLATE XXIII.

Leyden Jar Current—Foot-Bath Electrode.

122. Indications for Central Galvanization.—In diseases like chorea, neurasthenia, hysteria, and epilepsy, where the indication is to increase nutrition of nerve-tissue and produce tonic-sedative effects, central galvanization will give the best results.

123. Central Galvanization and General Faradization.—There are a number of diseases in which both methods of treatment may be employed on alternate days, much to the benefit of the patient. In applying electricity, the physician will utilize, in any given case, the known therapeutic properties of the electric current, precisely as he would the known therapeutic properties of any medicinal agent.

124. The best results are very often obtained by a judicious combination of both methods of treatment. Central galvanization will increase the nutrition of nerve-tissue, and, through its tonic-sedative properties, increase the stability of the entire nervous system. General faradization will develop the muscular system, by increasing its tone and buoyancy, while its reflex action on the central ganglia will augment the efficiency of central galvanization. One method of treatment simply adds to and sustains the effects produced by the other. The use of one or both will serve the physician in a large number of cases.

125. Current-Direction in Central Galvanization. The current passes from the positive electrode placed on the forehead, parietal eminence, and occiput, through the vital centers to the negative pole placed over the epigastrium. The importance of the structures influenced and the tonic-sedative, nutritive properties of the direct current give to this form of treatment a special value in routine practice. It has already been stated that Doctor de Watteville denies any action of the direct current on the pneumogastric and cervical sympathetic. The following is taken from a contribution of the late Doctor Brown-Sequard: "Recently, some bold physicians have tried to galvanize the cervical sympathetic nerves. This I did once in 1855 on my eminent friend Professor Ch. Rouget to try to relieve him from most violent headache. The effect was all that we could desire against the headache, but the galvanic

current acting, at the same time, on the sympathetic and the vagus (the simultaneous excitation of these two nerves cannot be avoided) produced such a dangerous syncope that I promised myself that I would never try again to apply galvanism to the cervical sympathetic of man." Both of these physicians are justly distinguished for the work they accomplished in the particular spheres in which they devoted the energy of their lives. To the physician several years in practice, acquainted with the idiosyncrasies of patients and the uncertainties of drug-action due to various causes, the opinions expressed by both Doctor Brown-Sequard and Doctor de Watteville will receive the respect due to these authors; yet central galvanization and galvanization of the sympathetic will still be used with good results, just as morphin and strychnin are now daily used, notwithstanding the fact that many fatal cases are reported from their use, judicious or otherwise.

126. In the applications of electricity to the cure of disease, every year—indeed, one may say every month—witnesses the birth of some new device whereby the control of the current, and its localization and dosage, are made more secure in the hands of the physician; so that accidents from interruption of the current, prolonged administration, or too great current-strength, are so surely and easily avoided that one can hardly conceive of their occurrence. The curative agents in daily use are dangerous when dangerously used. Electricity is no exception to this rule. Like all remedial agents, it is a two-edged weapon that cuts both ways. Whether the direct current acts reflexly or directly on the nerve-centers makes little difference, so long as good results are obtained, yet every physician can demonstrate for himself that weak currents from 3 to 5 milliamperes act on the cerebral centers. If they do not, how then can he explain the effect produced on his patient? The dizziness, vertigo, nausea, the tonic, exhilarating effects cannot be explained away by the psychical effects of "gleaming" batteries. It is remembered that Althaus ascribed the therapeutic properties of the direct current to reflex action. This

author believes that the fifth pair of nerves conveys the electric currents to the brain, where they act according to their specific properties. He further claims and cites a case at length that the cerebral centers cannot be influenced when the fifth pair of nerves is rendered unfit to convey inward electrical impressions.

127. The method of central galvanization is based, according to Rockwell, the author of the method, on the following four assumptions:

1. In functional diseases the pathology is not confined to the brain, the sympathetic or spinal cord, but the whole central nervous system is involved in the morbid process.

2. In chronic diseases, such as hysteria, neurasthenia, and epilepsy, it is impossible to determine the exact location of the disease in any given case; and if it were possible, the method of localizing the current is by no means determined. When the spinal cord is wholly at fault, the brain and sympathetic do not escape.

3. Mild galvanic currents increase the nutrition of the central nervous system.

4. The galvanic current cannot be strictly localized. In applications to the neck, the sympathetic, pneumogastric, and spine are affected, and isolated action cannot be obtained. In galvanizing the brain, it is impossible to say how much of the effect is due to reflex action and how much is due to direct action. There is the same difficulty in galvanizing the spine. Whether the effects of spinal galvanization are due to action on the spinal cord, on the sympathetic ganglia situated on both sides of the spinal column, or on the spinal-nerve roots, it is impossible to determine.

GALVANOFARADIZATION.

128. Origin and Value.—Doctor de Watteville introduced into medical practice a form of electrical treatment to which he gave the name of galvanofaradization. The method consists in uniting the secondary induction-coil and the galvanic battery in one circuit by connecting, with a wire, the negative pole of one and the positive of the other, attaching the

electrodes to the two extreme poles and sending both currents through the body. The utility of the simultaneous application of both currents must be patent to every one possessing a knowledge of their physiological and therapeutic properties. The parts on which the faradic stimulus falls are in a state of catalectrotonus; each current must therefore increase the therapeutic utility of the other. Vigorous faradization of the muscular system, even when strictly indicated, produces fatigue; the conjoined use of the galvanic current with its invigorating and refreshing qualities will enable the physician to obtain the therapeutic properties of the faradic current without exhausting or annoying the patient. Indeed, the effects produced on the patient by the simultaneous use of both currents are of the happiest kind, while faradization alone carried to its therapeutic limits would surely produce fatigue and exhaustion.

129. Indications for Galvanofaradization. — Galvanofaradization finds its special field in diseases of the abdominal viscera. It is well known that the paretic or atonic condition of the bowels is not a favorable factor for the action of faradic currents. If, however, a condition of catelectrotonus is first produced by the direct current, the alternating current will at once assert its well-known therapeutic properties. In corpulent patients, with pendulous abdomens, suffering with constipation, the combined use of both currents, known as galvanofaradization, has rendered much service. When both currents are used simultaneously, the same current-strength may be employed as if each were used separately. In the simultaneous use of both currents the physician has an agent capable of doing much good. It will be important to remember that the fatigue sometimes produced by general faradization may be avoided by the conjoined use of the galvanic current. Not only is the sense of fatigue avoided, but a feeling of strength and activity, or a desire to do something, physical or mental, is established. The patient treated is at once submitted to the tonic stimulating qualities of alternating currents acting in their most favorable conditions, and also to the tonic nutritive influences of the galvanic current. When non-striated

muscle-fibers are physiologically normal, they respond to rapidly interrupted faradic currents; but when paretic from any cause, they no longer act. In this condition the simultaneous use of both currents is indicated.

130. Interrupted induction-coil currents increase metabolism by their action on the muscular system and the sensory nervous system. The increased nutrition is therefore produced in two ways; viz., by muscular contraction and by stimulating the terminal sensory nerves. The influence of induction-coil currents on nutrition, without causing any muscular contraction, is steadily gaining credence among electrotherapeutists. The direct current influences nutrition by its action on cell-function, in promoting glandular activity. It modifies, in no way, respiratory exchanges. A study of their physiological and therapeutic properties gives sufficient ground for their simultaneous employment in a large number of diseases.

131. Choice of Currents.—It has been repeatedly stated in these pages that the selection of current requires the exercise of careful judgment, a thorough knowledge of the properties of the different currents, and a true conception of the pathological condition to be treated. In using the currents simultaneously, as recommended by Dr. de Watteville, the indications must be clearly posed and the dosage accurately regulated. In determining the current-strength and the duration of the séance the classic aphorism of Beard and Rockwell, "Better much too little than a little too much," should be always borne in mind.

132. Refreshing Power of Direct Current.—The classic experiments of Dr. G. V. Poore demonstrating the property of the direct current to increase the enduring powers of striated muscles, is a clinical proof of the value of both currents used at the same time. It is evident that if the direct current increases the enduring powers of skeletal muscles, the séance of general faradization or local faradization may be prolonged when aided by the simultaneous use of weak galvanic currents.

133. Experiment of Doctor Poore.—Doctor Poore's experiments were made for the purpose of demonstrating (*a*) the effect of direct currents on fatigued muscles, (*b*) the effect of direct currents on the power of muscles.

EXPERIMENT 1.—He instances the case of a patient that was able to hold out his arm horizontally with a weight of 17 ounces in the palm for 4 minutes, and then complained of great pain, fatigue, and inability to go on, but was relieved of the pain and fatigue at once by the passage of a direct current in a descending direction along the arm.

EXPERIMENT 2.—To demonstrate the effect of a direct current on the power of muscles, the person experimented on squeezed a dynamometer eight times at intervals of 10 seconds, with an average of 48½ pounds for each squeeze. With the aid of a direct current, eight more squeezes were made, giving an average of 59½ pounds. The last series of squeezes were 8 minutes after the fir t. The current-strength passed was never sufficient to cause muscular contraction.

PLATE XXIV.

Leyden Jar Current.

The X-Rays.

THE X-RAYS.

INTRODUCTION.

PRELIMINARY INVESTIGATIONS.

1. Static Discharges.—When static machines were described, it was noticed that the electric charges on the two prime conductors could unite in the following ways: (1) by a *conductive* discharge, when the poles of the static machine are united by thin wire, and the charges are allowed to unite by passing through the wire; (2) by a *disruptive* discharge, when the poles are not connected by any conducting material, and the discharge is compelled to take place through a dielectric, such as air and other gases; (3) by a *convective* discharge, when one of the charged conductors is pointed, and the charge of high potential collects on the point at so great a density that it is able to electrify the neighboring particles of air and repulse them, when these particles carry off part of the electric charge. Such discharges may take place either in gases or in liquids.

2. Appearance of Discharges.—The appearance of these various discharges is different. For instance, when the disruptive discharge takes place over a short distance, it consists of a thin, brilliant line of light. If the distance is increased to about an inch, it changes in appearance and adopts a zigzag line, caused by existing dust particles in the air; the spark takes the path of least resistance, and thus, so to speak, jumps from one particle to another in bridging over the air-gap. When the distance is increased still more, the form of the spark

will again change, so that, when the air-gap is as much as 12 inches, the spark consists of numerous ramifications. The brilliancy of these sparks depends on the strength of the current, that is, on the quantity of electricity partaking in the discharge; while the length of the spark will depend on the potential and the condition of the surrounding gas.

3. Color of Discharges.—The color of these discharges also varies; it seems that the spark melts and volatilizes small particles of the metallic conductors between which the spark is passing, and the gases produced in this manner are sufficient in quantity to change the color of the spark. Between iron the discharge is of a reddish tint, while between silver and copper it is greenish.

4. Brush-Discharge.—A brush-discharge will take place between the separated conductors of a static machine, if the latter is operated so as to generate a high potential. This discharge has the appearance of a brush with numerous branches, which are more numerous at the positive pole, and which seem to consist of sparks passing in rapid succession. Pointed conductors change this brush-discharge to a convective discharge of another form; the brush disappears and is replaced by a glowing stream of electrified particles of air. Moreover, there is here a difference between the discharges at the two poles; thus, the negative pole has a dark space which separates it from the glow. This *dark* space plays quite an important part when electricity is discharged through rarefied gases in vacuum-tubes, as will be seen later on.

5. Effect on Discharges of Rarefied Gas.—All these discharges change their appearance entirely when they take place in rarefied gases. It should here be noticed that a vacuum will not permit *any* discharge to take place between the poles of an electric machine, even with the highest potential obtainable and over so short a distance as .4 inch. A vacuum must therefore be considered as a perfect insulator. One would then naturally suppose that a discharge would be facilitated when permitted to take place in compressed air; but the contrary is the case. An increase in pressure also increases

the resistance of the air to a discharge, and air has been compressed to a pressure of 40 to 50 atmospheres, when it was found impossible to send a spark across so small a distance as .2 inch.

6. Effect of Imperfect Vacuum.—In pressures intermediate between that of the air and a perfect vacuum, the electric discharge undergoes a number of variations both as regards form, brilliancy, and color. These various discharges may be studied either by means of a so-called electric egg—which is an oval glass bulb provided with a conductor in each end, and connected with an air-pump, by means of which the pressure can be varied—or by means of the well-known Geissler tubes, which usually consist of two small bulbs of glass connected by a narrow tube of the same material. They have small platinum wires fused into their extreme ends, and are made of various kinds of glass, and filled with different gases. The more important discharge phenomena must be studied by means of Crookes tubes, about which more will be said further on.

7. By letting these discharges take place in an electric egg, while the air-pressure is gradually diminished, the following phenomena will be noticed: At first, while no exhaustion has taken place, the spark will pass across in its usual form; when rarefication begins, the spark will begin to spread and be more diffused, little by little occupying the whole width of the tube, and lose in brilliancy, until it becomes more of a nebulous, pale, reddish light. The immediate neighborhood of the two electrodes is distinctly different in appearance. At the negative electrode of the cathode there is a beautiful violet glow, which is separated from the electrode by a dark space; this violet light is also to be found, but less brilliant, at the anode.

8. Striæ.—At certain pressures, the general glowing discharge breaks up into cup-like patches of light, called *striæ*, which first form at the anode and move a certain distance toward the cathode, then fill the whole space between the electrodes, vibrating back and forth. These discharges are particularly beautiful in nitrogen gas. The small particles of

metal torn from the surface of the cathode and ejected by it, are rich in fluorescent and phosphorescent rays, and have therefore been utilized in producing beautiful effects by making the surrounding tube of uranium glass or by inserting the tube in solutions of quinin. All of these discharges are sensitive to the influence of a magnet, in whose presence they will either be partly bent out of their path and then again resume their original direction, or be bent permanently out of their original direction, following a path similar to that of a projectile when falling under the influence of gravitation.

Until Crookes began his experiments with tubes of high vacuum, the pressures in the various bulbs were relatively high, mostly about 30,000 M, M meaning one-millionth of atmospheric pressure. Crookes brought the pressure in his tubes down to 1 or 2 M.

9. Crookes Tubes.—The Crookes tubes are made in numerous varieties as to form and number of electrodes, but there are certain forms that are used more than others, and that will here be described. Fig. 1 shows a form very frequently used, and by means of which some of the fundamental experiments were carried out. It consists, in the main, of a circular bulb with four extensions, into each of which an electrode has been fused. These latter are necessarily made of platinum, as the rate at which this metal expands under the influence of heat is practically the same as that of glass, and therefore no leakage will take place where the wires enter the glass. It is not necessary that the inner extremities of the wires be platinum; they may be, and preferably are, made of aluminum, and are then mechanically united with the platinum wires. There are three anodes,

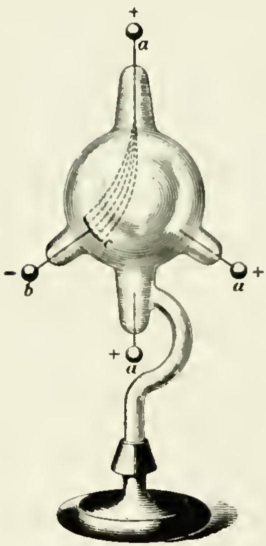

Fig. 1.

marked a, and one cathode b; the latter has a concave aluminum disk c. Any of these anodes may be used in conjunction with the cathode.

10. Experiment With Crookes Tube.—When this tube was in possession of a fairly low pressure, and the cathode and one of the anodes were connected with a source of high E. M. F., a stream of bluish light passed from the cathode to the anode, as shown by the dotted lines in Fig. 1. On increasing the vacuum until it was just low enough to permit a discharge to take place, the blue stream disappeared, and there was a nebulous, greenish light along the inside wall, while on the glass opposite the cathode there appeared a phosphorescent spot of greenish light. It was also noticed, as seen in Fig. 2, that the radiations proceeded in straight lines and crossed one another at a common focus. The choice of anodes, among the three, made no difference, the stream retaining its original position.

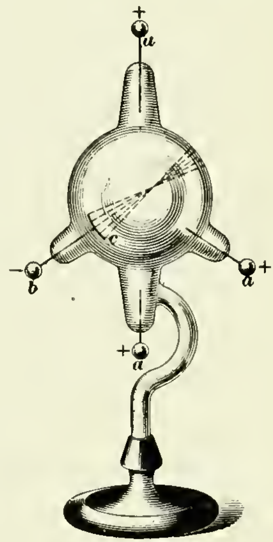

Fig. 2.

11. Crookes's Explanation.—It was noticed in these experiments that the dark spot, which separated the cathode from the stream of bluish light when the exhaustion was less complete, increased in size when the vacuum grew higher, so that, when the exhaustion was more complete, this dark spot extended throughout the whole bulb. In regard to the phenomenon, illustrated in Fig. 2, Crookes was of the opinion that, in carrying the exhaustion so far, the remaining electrified molecules of air had so much more room that they could travel in straight paths without striking one another, and could therefore reach a velocity that they otherwise were unable to attain. A result of this high velocity was the force with which they would strike the wall of the bulb

when they reached the end of their path, the force of this so-called bombardment being so great as to produce a fluorescence of the glass.

12. The "Bombardment" Theory.—Crookes produced several devices for proving the existence of this action and force of the molecules. One is shown in Fig. 3; it shows a bulb-like tube, with a cathode *b* at one end and an anode *a* near the other. The latter has at its extremity a Maltese cross *d* of aluminum, which is hinged on to the anode. When the bulb is operated, a stream of molecules will proceed from the cathode toward the other end of the bulb; those that do not collide with the cross will strike the end of the bulb, there causing fluorescence. But, as some of the molecules were repelled by the cross, there will remain a spot on the bulb that remains dark and has the appearance of a shadow cast by the intercepting cross, as shown in the figure. After a while, the brilliancy of the light decreases; and when the tube is tipped, causing the cross to fall forward, the whole effect is reversed, as now the dark spot is brightly illuminated, while the surrounding parts appear less so.

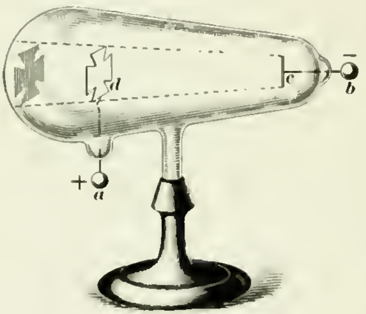

FIG. 3.

To prove the mechanical action of the molecules, Crookes constructed an apparatus as shown in Fig. 4. Here, *d* is a small wheel made of aluminum, and is connected with the cathode *b*. On sending a current through the bulb, the vanes of the wheel would be enveloped in a violet light, when the vacuum was low; but, on increasing the latter, the light would disappear

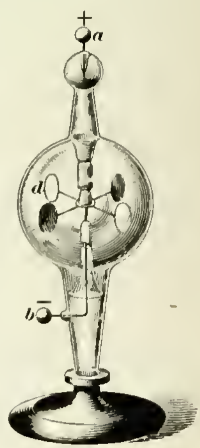

FIG. 4.

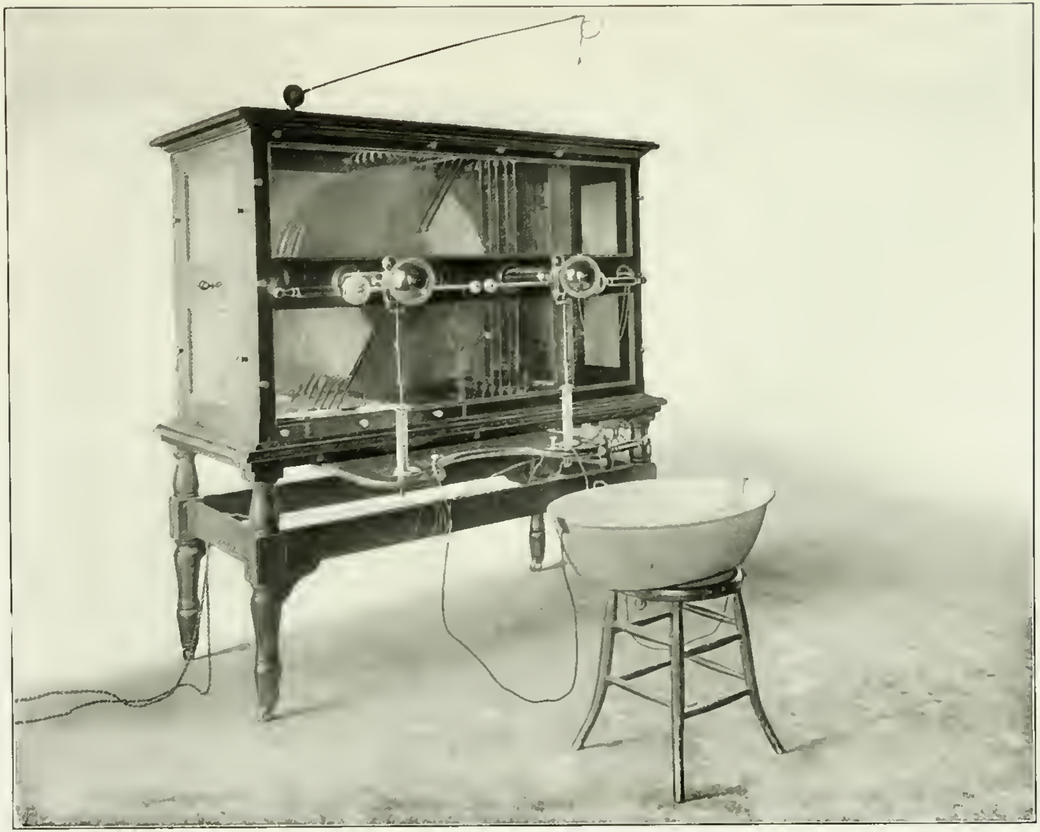

PLATE XXV.

Leyden Jar Current—Foot-Bath Electrode.

and the wheel begin revolving, caused by the reaction of the repelled molecules on the vanes.

In a tube as illustrated in Fig. 2, it was found that, at the spot where the focus of the rays is situated, the heat was so great that a temperature as high as 4,000° to 5,000° F. was developed, sufficiently high to melt a small piece of irido-platinum.

13. Lenard's Investigations.—The investigations of Crookes were continued by Lenard in another direction. As a result of his investigations Lenard discovered that the cathode rays could be carried on to the outside of the generating-tube. Of many different tubes that he built, he settled on one, in which the cathode *b* consisted of a thin disk of aluminum *c*, Fig. 5, which was surrounded by a heavy brass cylinder *d*, connected with the anode *a*. The end of the tube was provided with a metal cap *f*, in which was a small aperture; the glass thus laid bare was covered with a piece of thin aluminum *e*, called a *window*. The latter and the anode were electrically connected with each other and with the earth. On sending an electric current through the tube, it was noticed that, outside the window in the open air, a bluish glow extended in all directions to a distance of about 2 inches, as seen in the figure. The effect of the window was supposed to be the dispersion of the parallel cathode rays in all directions.

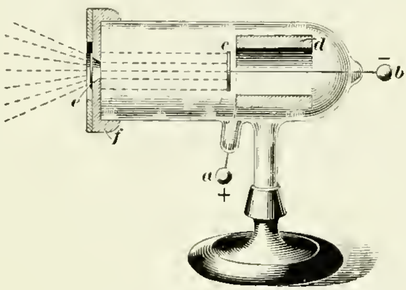

FIG. 5.

In general, the rays phosphoresced the same substances that were phosphorescent in ordinary light. By interposing tin-foil or glass, the effect of the rays was greatly reduced; but was not diminished by the interposition of gold-leaf or silver- or aluminum-foil. Experiments made by letting the rays pass through numerous substances showed varying effects, so far as their transparency was concerned, and showed also that they affected

a photographic plate. It must be borne in mind that these cathode rays, though in many respects similar to the later discovered X-rays, are not identical with the latter.

NATURE AND MANIFESTATION OF X-RAYS.

14. Roentgen's Discovery.—After having followed the cathode rays to their final development, we come to a point where a new field for its application was suddenly opened up, and where properties of the rays were discovered that were hitherto supposed to be non-existent. The honor of this discovery belongs to Professor Roentgen, of Würzburg, Germany. He found that the nature of the cathode rays is changed after they strike the wall of the discharge-tube or some material placed in their path in the tube itself or outside of it. These new rays are called *X-rays* because their real nature as yet is unknown, though various theories have been propagated as an explanation of their source and action.

15. Origin of X-Rays.—It will be remembered that Crookes already found a fluorescent spot on the wall, opposite the cathode in his discharge-tube. In reference to this spot, Roentgen found the following properties, which he describes in the following words: "Judged from experiments bearing directly on this question, it is certain that the spot on the wall of the discharge-tube, which fluoresces most decidedly, must be regarded as the principal point of the radiation of the X-rays in all directions. The X-rays thus start from the point at which, according to the researches of different investigators, the cathode rays impinge upon the wall of the glass tube. If one deflects the cathode rays within the apparatus by a magnet, it is found that the X-rays are emitted from another spot, that is to say, from the new place where the cathode stream terminates. . . . The X-rays are not identical with the cathode rays, but they are generated by the cathode rays at the glass wall of the discharge-tube."

16. Anticathode.—It is not necessary for the cathode rays to strike the wall of the tube; they may also be intercepted by some substance placed inside the tube. The result is the same; as soon as the cathode rays impinge on the substance, X-rays are reflected in all directions. The object against which the cathode rays thus collide is called the *anticathode.*

17. Bartelli's Experiments.—Whether the X-rays are coexistent with the cathode rays, when the latter are projected from the cathode, and separate themselves after striking the anticathode, or whether they first are called into existence after the cathode rays have reached the anticathode, has been a question on which opinion differs. Experiments performed by Bartelli seem to show that the first explanation is the correct one. He found that, if a photographic plate was placed inside a Crookes tube in the direct path of the cathode rays, and the latter then deflected by means of a magnet, the plate nevertheless had been subject to some photographic action. This proved that there were some parts of the cathode rays that were not acted on by the magnet, and that proceeded in their original direction. He also placed photographic plates both inside and outside of the Crookes tube; the former plate was in the direct path of the cathode rays, while the outside plate was exposed to the resulting X-rays. It was found that the inside plate was acted on, photographically, much more strongly than the outside one.

18. Another question, yet unsettled, is whether the X-rays consist of streams of material molecules, as supposed by Crookes and later on by Tesla, or whether they are, as Roentgen and the German scientists in general seem to think, a form of ether-waves. Roentgen favors the idea that these ether-waves are longitudinal in their action, while French investigators are more of the opinion that they are of the transverse form, and are nothing but invisible or dark light.

19. Focus-Tubes.—Various forms of Crookes tubes have been proposed for the production of X-rays; we will consider only those that have shown themselves to be the most efficient.

Among these is one of the early forms, shown in Fig. 6. Here the anode is formed of platinum, and serves both as an anode and as an anticathode. The cathode is concave, and the rays are therefore focused to a point on the anode; for this reason the resulting X-rays have a better effect in producing clearer shadows, particularly if the object is several feet away from the tube. This form is fully satisfactory up to a certain voltage; beyond this, the current is apt to follow a path along the outside of the glass tube. For this reason it has been found necessary to place the electrodes farther apart.

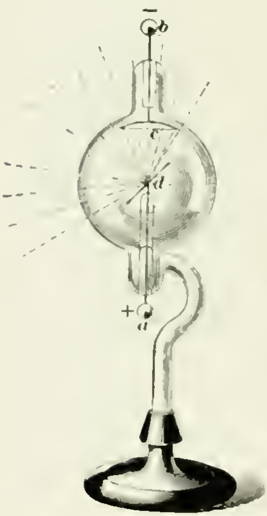

Fig. 6.

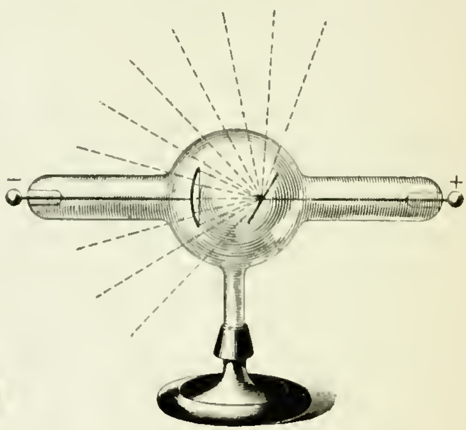

Fig. 7.

A tube of this class is illustrated in Fig. 7, where the distance between the electrodes is more than double that in Fig. 6, thus making it possible to use a much higher potential. In either of these tubes the anode *d* is a disk made of platinum, the cup-shaped cathode *c* being made of aluminum. Tubes in which the cathode has this form are called *focus-tubes*, because the cathode rays are reflected to a common focus near the anode.

20. Standard X-Ray Tube.—A focus-tube called the *standard X-ray tube*, because it may be used with any kind of generator, is shown in Fig. 8 (*a*). In case a *direct* current is used, such as that which emanates from an induction-coil, the cathodes *b*, *b* are connected together and constitute one

cathode, while the anode a is common for both. If *oscillating*, or *alternating*, currents are used, then b, b constitute the two electrodes, and either will alternately be anode and cathode. One of the most recent forms is shown in Fig. 8 (b), in which the anticathode d is not used as an anode, but is entirely insulated on a glass bracket. The anode a' is formed as a ring, through which the rays from the cathode c must pass on their way to the anticathode. By not using d as an anode, the tube is not

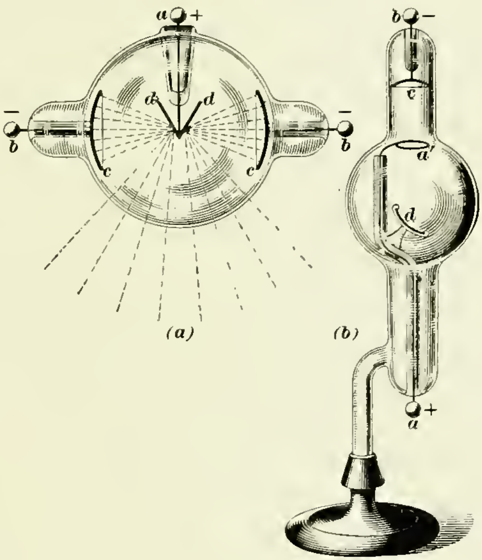

FIG. 8.

liable to blacken on the inside. When alternating currents are employed, the cathode and anode are duplicated, and used in conjunction with one anticathode.

21. It will be observed that, in the various focus-tubes shown, the focus of the rays does not fall exactly on the anode or anticathode, neither does the focusing of the rays take place before they strike the platinum anode. How great this distance is does not seem to matter much if kept within moderate limits, as the cathode rays do not seem to disperse again after they have come to a focus.

ACTION OF A FOCUS-TUBE.

22. Variation in Action.—The action of a focus-tube is not constant; it is not of such a nature that all it requires is connection with the source of electric energy, and that then the tube, like an incandescent lamp, is immediately in full action. On the contrary, it takes some time, often hours, before the tube will come to a full activity in emitting the desired quantity of X-rays; moreover, after this state has been reached, it does not remain, for after a certain time the action again diminishes. To vary within certain limits is characteristic of Crookes tubes.

23. Nature of Action.—If the vacuum is low, and therefore the resistance small, there will appear a bluish light between the anode and the cathode along the wall of the tube. At this stage the X-rays will be few—enough to act on a photographic plate, but not sufficient to bring the screen to fluorescence. After a time this blue color will disappear and be replaced by a stream of greenish hue. At this point the whole tube fluoresces both in front and behind the anticathode, except for a narrow zone in line with and encircling the former. Continuing the operation, the greenish light behind the anticathode will little by little disappear, while in front the light increases in brilliancy. At this stage the effects of the X-rays are at their best, and if a hand, for instance, is placed between the tube and the fluoroscope, a most decided difference between the bones and the flesh will be indicated. After this stage has passed, the penetrating power of the rays seems to increase still further—more so than is advantageous for making examinations of the human anatomy, as they seem to be capable of penetrating the bones just as readily as the flesh, and do not make enough distinction between them.

This is only when the hand is held always in the same position. A tube too good or X-rays too penetrating have not yet been found. When the rays are so penetrating that there is no distinction between the bony and the muscular structures of the hand, it is only necessary to remove the hand to a greater distance from the tube, since the energy of X-rays varies

inversely as the square of their distance from the source. We know, indeed, that in making a fluoroscopic examination of the hand, one instinctively moves the fluoroscope to and from the tube, in order to find the position where the parts of the hand are best differentiated. It is necessary to have several good tubes, because one may break in handling or some other accident may occur, but it is not necessary to have one tube for examining the hand and another for examining the trunk. With a good tube, all parts of the body can be examined by regulating the position of the tube and the body according to the law of "inverse squares." This law has been curiously lost sight of in X-ray examinations and in the selection of Crookes tubes.

24. Explanation of Change of Vacuum.—The explanation of this is to be found by considering that even at a high vacuum there is still some gas present, which lowers the efficiency of the tube. When a current is sent through the tube for several hours, its efficiency is constantly increasing until a certain maximum is reached. It seems that during this treatment the remaining gas has been occluded by the walls and electrodes of the tube, and that therefore the vacuum has been constantly raised. After a tube has been in use for some time, the vacuum is getting too high even for a current of the highest tension to pass through, and then the procedure will have to be reversed; that is, the vacuum must, by some outside means, again be lowered so as to come within the power of the current at disposal.

25. Reducing the Vacuum.—For this purpose there are several means that may be employed. After shutting the current off, the usual method is to heat the tube gently, by means of an alcohol-lamp or a Bunsen burner. This must be done carefully all over the tube, never letting the flame play too long against one spot. If the tube is supported horizontally and sends its rays to a screen, the heating may be done while the tube is in its original position; after the heating has been accomplished, the current is again put on, and the effects judged from the appearance of the fluorescence on the screen.

But it may be some time before this point is reached. The tube may have been heated repeatedly, and still the current may refuse to pass through the tube, and prefer instead to pass outside along the glass of the tube, or simply between the discharge-rods of the induction-coil or static machine. Under these circumstances the heating must be continued until the desired reduction of the vacuum has been attained, unless other means are at hand that may be used in conjunction with the simple heating of the tube.

26. Crookes's Method.—Crookes used a small supplementary tube, situated near the extremity of the main tube, and placed in the former a small piece of caustic potash. By exposing this extreme end to heat, the potash will expel some vapor, derived from the water, of which the potash has retained a small amount. In this instance the effects are very sudden, and the heating must be carefully done, as even a little heat is likely to liberate too much gas and lower the vacuum below the desired point.

27. Other Methods of Reducing Vacuum.—Dr. Graves, of St. Louis, while working with a tube through which the strongest current could not pass, accidently dropped a piece of tin-foil that he held in his hand on the cathode-region of the tube, and the tube immediately glowed with a brilliant radiance. Applying tin-foil to the cathode-end of the tube is now recognized as one of the best means of reducing vacuum and getting a current through a high-vacuum tube. Another method recently advocated is to wrap the cathode-end of the tube in damp cotton-wool connected to the cathode-wire. If the vacuum cannot be reduced by the application of heat to the region of the cathode, or by coating the cathode-end with tin-foil or damp cotton-wool, the tube must be sent to the maker for reexhaustion. To reexhaust a tube is a questionable procedure, because it never attains its original efficiency, its working capacity being only 15 or 20 per cent. of the original.

28. Action of Focus-Tubes.—It has already been stated that the focus-tube at low vacuum shows a bluish light along

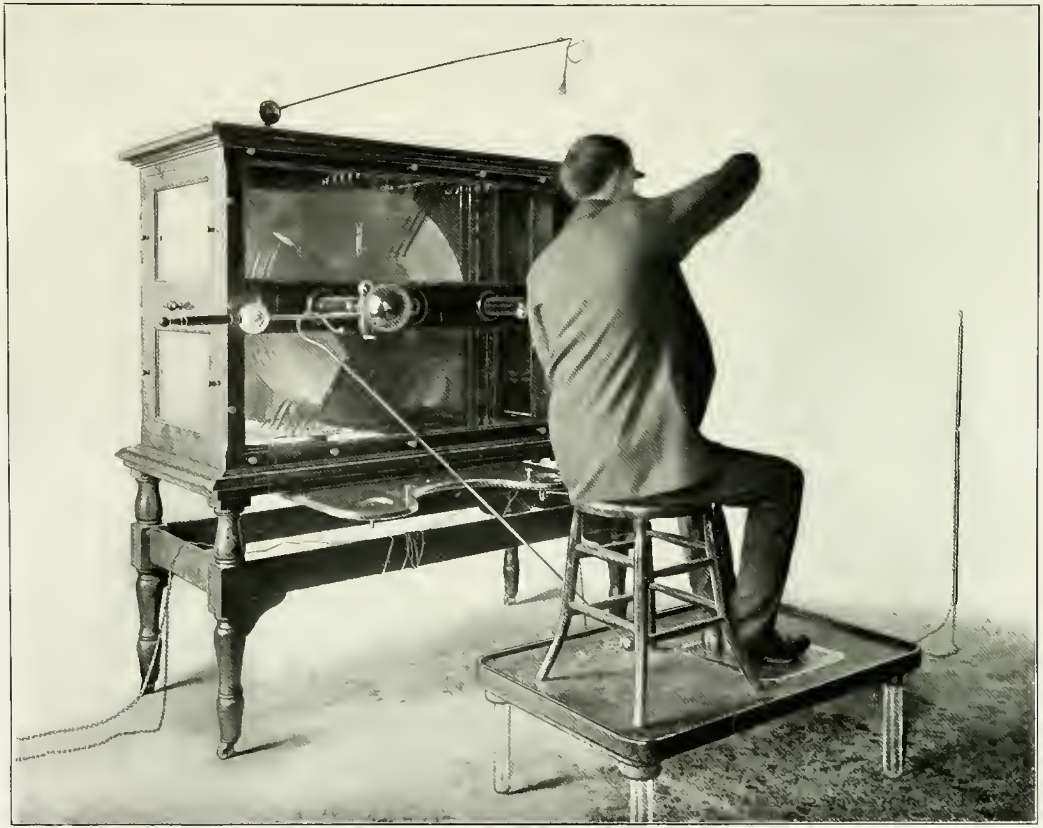

PLATE XXVI.

Posture in Treatment of Shoulder-Joint Pain.

the wall of the tube. If this light is not too strong, it will soon disappear and make room for the greenish glow that is present when X-rays are not profuse. On the other hand, should the bluish light be present all over the tube, it may take hours before the latter will disappear; and should the vacuum be so low that the light has a reddish and even a whitish tinge, then the tube would require too much time and energy to raise its vacuum to a point where it would be useful for practical purposes.

That a tube shows the faint bluish light and subsequently the characteristic greenish light, does not of necessity prove that it is an efficient tube. It may be so in its range—that is, in utilizing a current of relatively low pressure—but the amount of X-rays developed may be very limited and of short range. To be of more use, the vacuum must be raised so as to require a current of more pressure. This is accomplished by sending a current of moderate strength through it for some time, and watching the tube simultaneously with the discharger. If everything works satisfactorily, the vacuum should gradually increase, demanding at intervals a widening of the air-gap between the discharge-rods. The latter may, when the operation is begun, be about an inch apart; as the vacuum increases, the resistance of the tube is also increasing, and will after a while refuse to let the current pass through. The current will then choose the easier path, and in the form of sparks jump across the gap between the discharge-rods. On increasing the distance between them, the discharge will again take place through the tube, until the resistance of the vacuum is again in balance with the outside resistance, demanding another increase of space between the discharge-rods, and so on until after a while a vacuum is reached that demands a spark 6 to 8 inches long between the discharger in order to balance the resistance through the vacuum. This is the point to aim for, if good, efficient work is to be done, and if the tube is to remain cold.

29. Overheating the Tube.—Sometimes matters will not pass off as smoothly as this. When another tube is treated in the same manner, it may refuse to let the current pass

without getting unduly heated. At certain intervals the tube may get so hot that the hand is unable to hold it, after the current has been turned off. Under these circumstances the vacuum is lowered, permitting a much heavier current to pass, while the anode becomes of a dull-red color, showing that the tube is exposed to more current than is safe for it. There may now be a sudden increase of current, when the discharge changes its color to blue, red, and white, and finally an arc is established between the electrodes, which stage signalizes the end of the tube's useful existence. Even if the current is shut off before matters proceed thus far, the heating of the cathode and the anode will always be accompanied by a decrease of the vacuum, and must therefore be avoided. If such heating takes place, the current must be shut off at intervals and the tube allowed to cool, when the treatment can again be continued.

30. Length of Tubes.—It was mentioned before that the spark from an induction-coil, or a similar source, will at times pass outside the tube between the electrodes in preference to going through the tube. That the distance between the two electrodes, measured along the outside of the glass tube, must be greater than the air-gap between the discharge-rods, is a matter of course, as otherwise the whole current will pass outside the tube. For sparks less than 4 inches in length any tube will be sufficiently long, but not for sparks that go up to 10 or 12 inches. In using tubes that have an outside distance between terminals of about 6 inches for sparks of this length, the discharge will not be likely to go through the tube, particularly if the outside should have a deposit of dust particles, which usually is the case, as the dust is attracted by the inductive influence existing all around the tube.

31. Advantage of Several Tubes.—This possibility of increasing the vacuum makes it advisable to have several tubes on hand, as they can then be used in progression. For instance, a 4-inch tube could be used as a 2-inch tube by heating it and thus lowering the vacuum (by 4-inch is here meant a tube suited for a 4-inch spark between the discharger). A 6-inch tube may be used as such, but will gradually increase

in resistanee, and will demand longer sparks—say 8, 10, up to 12 inehes. The 4-inch tube will also be gaining in vacuum, and both tubes will gradually have to be advanced to heavier work, until after a while one of them has to be disearded. In the meantime, new tubes of lower vacuum have been secured, of, say, 2- or 3-inch sparks. When used as sueh they will be of greater longevity, and will retain their original pressure much longer than if used for heavier work.

32. Comparison of Sparks.—It is well to remember that a 2-inch spark of a large coil is not the same as a 2-inch spark of a smaller coil. The first produces sparks that may be said to be "fatter" than those of the seeond eoil; that is, they are part of a heavier current. We have a similar instance when letting a thiek and a thin fluid, respeetively, drip from the neek of a bottle. Drops of the first fluid will be larger and heavier and contain more matter than drops of the other fluid. In the same manner, the sparks from the large coil will have more volume and be able to do more work than sparks from the smaller coil. Attention is called to this, as it sometimes happens that a tube will take a 5-ineh spark from a small eoil, but will take a 2-ineh spark from a larger one only after considerable overheating. This does not prove that the larger eoil is of low effieieney; it shows rather that the coil sends more energy through the tube than the latter can take care of, and that the tube, for the present at least, is unable to do heavy work. It may do so after some time, when it is more exhausted by the influenee of the eathode rays. When a tube heats in this manner, and to sueh an extent that the anode partakes of a dull-red eolor, it proves that the tube is worked beyond its present capaeity and that it is likely to break down.

SOURCE OF ELECTRIC ENERGY.

33. The eleetric energy required to produee the X-rays in a focus-tube may be provided in three different ways: (1) by *static* maehines, sueh as those of Holtz or Wimshurst; (2) by induetion-coils; (3) by oseillating eurrents as provided by Tesla transformers.

STATIC MACHINES.

34. Method of Operating Focus-Tubes With Static Machines.—The construction and the operation of these machines have already been gone into fully, and little needs to be added to explain their use in connection with focus-tubes. The main thing is to secure a tube adapted to the current from this machine. It has been shown in Art. **14**, Section 5, page 10,

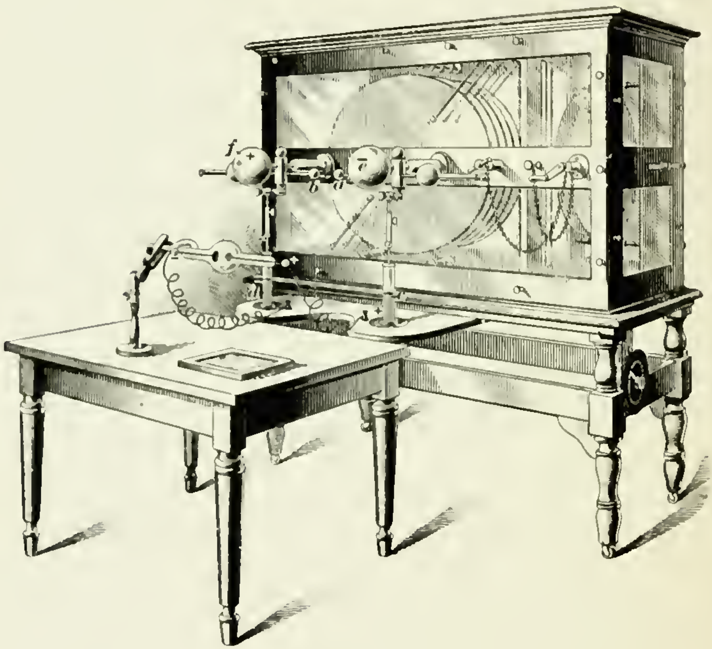

FIG. 9.

how to distinguish between the poles by means of the appearing brush-discharge. The X-rays can now be produced either with Leyden jars in the circuit or without them; the first method is preferable, however, on account of the function of the jars in acting as condensers. Connection between the machine and the tube is shown in Fig. 9. The prime conductor *e* is of negative potential, and connects with the inside of the jar *c*; the conductor will therefore induce a positive charge on the outside

of the jar. In the same manner, the positive conductor *f* will induce a negative charge on the outside of jar *d*. The outsides of the jars *c* and *d* are connected, respectively, with the anode and cathode of the focus-tube.

35. The successful operation of the tube depends now on the proper adjustment of the sparking-distance between the discharge-rods *a* and *b*, and this depends again to some extent on the size of the Leyden jars. It is not advisable to have these jars too large for ordinary work, as the spark may be too strong for tubes of lower vacuum. A jar with a tin-foil area of from 10 to 12 inches is amply large enough for all work up to 5 or 6 inches sparking-distance. It has already been explained how the sparking-distance depends on the vacuum of the tube. Ordinarily, a distance of up to 3 inches will be sufficient, but

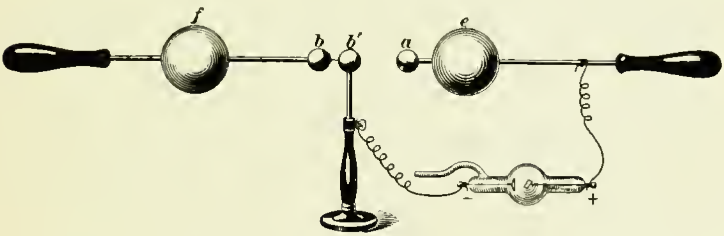

FIG. 10.

it is well to begin with a spark of about $\frac{1}{2}$ inch, and to increase this until the proper fluorescence of the screen has been attained. It is seen that in the present combination the focus-tube is in parallel with the discharge-rods, and that the spark passes between said rods simultaneously with the uniting, through the focus-tube, of those charges that exist on the outside of the jars. The latter can also be arranged in series with the spark-gap, as shown in Fig. 10. Here the Leyden jars are omitted, and the sparking takes place between the discharge-rod *b* and an auxiliary rod *b'* that connects with the cathode of the tube, the anode connecting with the other discharge-rod *a*, as seen in the illustration.

36. Method of Operating Crookes Tube With Static Machine.—There are three different methods by which

Crookes tubes may be operated by static currents; namely, the convective-current method, the interrupted-current method, and the oscillating-current method.

37. Convective-Current Method.—The tube-terminals are connected directly to the prime conductors of the static machine by a piece of insulated copper wire about 3 feet long. The anode is connected to the positive prime conductor, and the cathode to the negative prime conductor. With the plates in rapid motion (about 200 revolutions per minute), draw the discharge-rods 4 or 5 inches apart. The large Leyden jars may be in position on the shelf and the switch-handle turned to the word "Spray." This method of operating the tube causes no noise, no heat, and is in every way eminently satisfactory.

38. Interrupted-Current Method.—The current-interrupters devised by Dr. S. H. Monell are secured upon the ebonite handles of the discharge-rods, with the eyelets of the interrupter turned outwards. The wire attached to the cathode-terminal of the tube is hooked, by its other extremity in the eyelet of the interrupter, on the negative discharge-rod. The other wire attached to the anode of the tube is connected to the interrupter on the positive discharge-rod. The ball of the interrupter is in close contact with the ball of the discharge-rod. The discharge-rods are separated 3 or 4 inches. Start the plates in rapid motion, and regulate the spark-stream at each interrupter to its maximum length. The large Leyden jars may be in position on the shelf with the switch turned to the word "Spray." The spark-stream between the ball of the interrupter and the ball of the discharge-rod produces very little noise. The interrupters increase the energy of the current and render the method correspondingly valuable.

39. Oscillating-Current Method.—In this method the Leyden jar currents are utilized. Place the smallest Leyden jars on the shelf and turn the switch to the word "Spray." The charge on the outside of the jar connected to the positive pole is negative; the charge on the outside of the jar connected to the negative pole is positive. This must be remembered in connecting the tube to the machine. The cathode-terminal of

the tube is connected to the binding-post on the positive side of the machine, and the anode-terminal to the binding-post on the opposite side. With the machine in rapid action, the discharge-rods are gradually separated until the tube glows with maximum radiance and with a steady image. If the image is not steady, reduce the distance between the discharge-rods until it becomes steady.

40. How to Test a Static Tube.—According to Dr. S. H. Monell, every static tube should be submitted to the following test: The tube is connected as described in the convective-current method. With the discharge-rods in contact, start the machine in rapid action. The discharge-rods are slowly separated, and the tube closely observed. Now one of three things will occur. When the discharge-rods are $\frac{1}{2}$ inch apart or less, a blue stream will pass between the reflector and the cathode. The vacuum is then too low, and the tube requires to be further exhausted. If the tube has sufficient resistance to push back a spark-stream of $\frac{3}{4}$ or 1 inch with a feeble production of X-rays, it may, by proper manipulations, be coaxed up to a good working capacity.

When the vacuum is sufficiently high to resist the energy of a spark-stream from $1\frac{1}{2}$ to 2 inches in length, it is available for the best X-ray work and will need no further manipulations. The vacuum may be so high that it resists the current when the discharge-rods are separated beyond sparking-distance. A tube of this vacuum should be manipulated as described in Arts. **26** and **27**.

41. How to Raise Low Vacuum.—Change the position of the tube so that the anode and the cathode are reversed. Allow the current to pass for a few minutes and test again with correct polarity. If this succeeds, the tube is ready for work. Should this method fail, use Leyden jar currents. Place the smallest Leyden jars on the shelf, with the switch over the word "Spray." Connect the anode-terminal of the tube to the binding-post on the negative side of the machine, and the cathode-terminal to the binding-post on the opposite side. Start the machine in rapid action, and draw the poles gradually

apart until the spark-stream splits and the tube glows. The discharges should be allowed to pass through the tube for 5 minutes. The machine is now stopped and correct polarity used. The discharge-rods are placed in contact, as in the convective-current method. Start the plates in rapid action, and draw the discharge-rods apart until the spark-stream wavers. The spark-stream should be continued for about 10 minutes. If the tube is worth manipulating, it will now produce efficient X-rays.

42. Changes in Vacuum.—The vacuum of a Crookes tube is subject to changes. When in use it is increasing, and rest tends to reduce the vacuum. This variability of the vacuum, this tendency to increase during work, determines the life of the tube. A tube is said to be good for 60 hours of continuous use. The changes in the vacuum of a tube depend a great deal on primary exhaustion. If the vacuum is manipulated by electrical discharges instead of being exhausted by the mercury-pump, it will cause much more trouble when in use. It is very important that the tube be exhausted by the mercury-pump alone, and that it have no value depending on electrical manipulations before the physician purchases it.

43. Advantages of Static Machine.—1. It generates its own current and can be operated with equal facility in the small town or the large city.

2. Primary batteries, storage-batteries, or commercial currents are not required for its operation.

3. Physiology and clinical experience assign the static machine a very important therapeutic position.

4. With proper care, the modern static machine is always ready for use.

5. It takes but half a minute to connect the tube to the machine, and in a minute's time the static tube is glowing.

6. There is no complicated apparatus to care for when using a static machine to operate a Crookes tube. Everything is simple and easy.

7. It does not cause depilation or dermatitis.

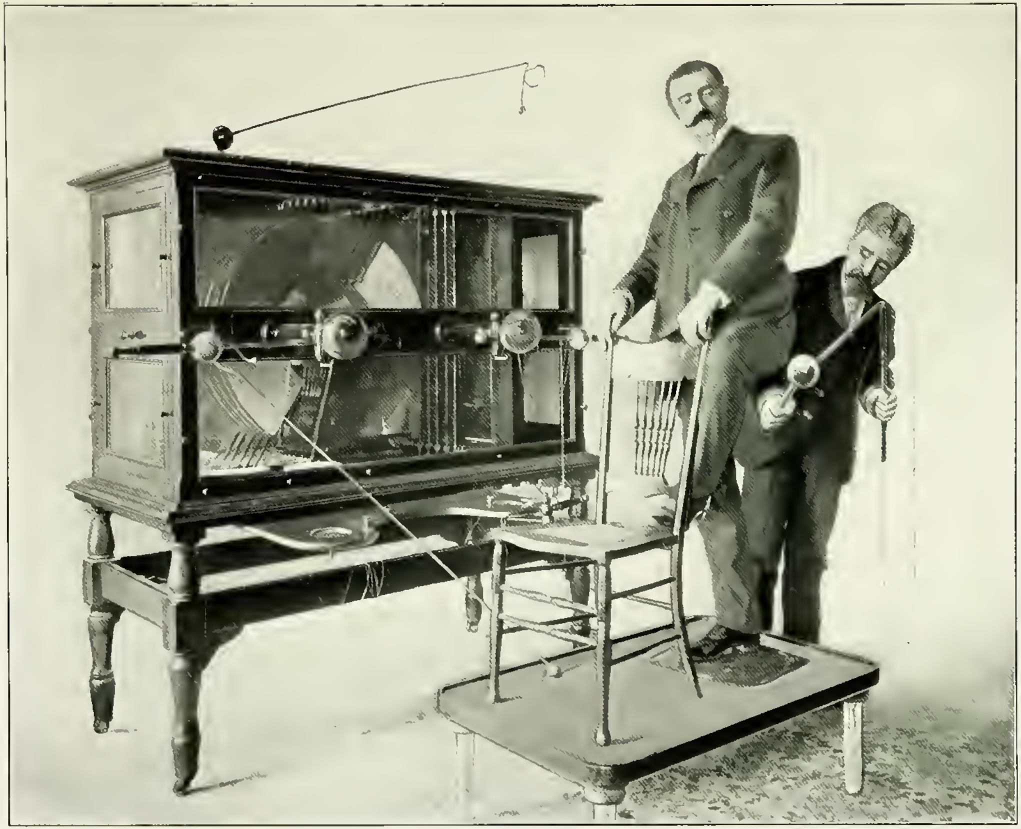

PLATE XXVII.

Posture in Treatment of Sciatica.

8. It equals in X-radiance the best coil made, costs very little for repairs, and does not "burn out."

9. The modern therapeutic static machine can be purchased for about the same price as a good coil.

When Professor Roentgen, in January, 1896, made known his discovery of X-rays, the induction-coil was believed to be the only electrical source capable of producing X-rays. The voltage and amperage of the static machine were well known long before Professor Roentgen's discovery; but in order to become the electrical source for the generation of X-rays in the physician's office, in hospitals, and in sanitariums, the static machine needed a tube whose construction and vacuum were adapted to its currents. In the latter half of 1897 this tube was supplied, and is known as the *Monell static tube.*

44. Disadvantages of Coils.—1. The Ruhmkorff coil requires for its operation the direct street current or a storage-battery, which must be charged from the street current. The Tesla coil is actuated by the alternating current only. Both of these coils depend on the street current for their efficient operation, and therefore cannot be used in towns unprovided with these electrical sources.

2. While a good coil produces brilliant X-rays, it has no other value in a physician's office. The coil-apparatus cannot relieve pain, give tone to the muscular system, regulate the functions of the human organism, produce sleep, increase tissue metabolism, increase the excretion of urea, carbon dioxid, and water, or regulate pulse and temperature when functionally deranged. The coil has no therapeutic value whatever. It produces brilliant X-rays, but the physician has no further use for it.

3. When fed with heavy currents it is apt to produce disastrous burns. By proper technique the danger of burns from coil-currents may be much reduced, yet the number and severity of reported cases of *Dermatitis Roentgeni* cannot fail to influence the physician when purchasing an X-ray outfit. The X-ray does not burn: it is the current used that burns. The static current does not burn without the X-ray; it cannot therefore burn with the X-ray.

4. Heavy currents may burn a coil. A burned coil costs a great deal to repair, or it may mean a new coil.

5. The operation of a fine-coil apparatus provided with break-wheel, motor, and rheostat is by no means simple. It is expensive and troublesome to keep such an apparatus in first-class working condition.

INDUCTION-COILS.

45. Operation.—It is unnecessary to say that coils producing short sparks only will not be suitable for the various duties they will have to perform in connection with medical work. Such coils may be sufficient for ordinary experimental work and for parts of the human body of shallow depth, such as hands, etc. When it comes to investigations of the trunk, a coil with a spark-length of 8 to 10 inches will be required. In using a coil of the latter size, there are certain precautions needed in its proper handling. If the person is possessed of a weak heart, the full charge of such a coil from both terminals may be fatal. Even a charge from a 2-inch coil is so severe that it will long be remembered. Connecting-wires without good insulation should not be used with an induction-coil, and the rule, *never to touch any part of the apparatus unless the current is switched off*, should be followed implicitly. The only exception to this rule is in the regulation of the interrupter; the tension-screw of the latter can—in fact, must—be regulated while the coil is in operation. It is advisable, therefore, to arrange the connections so that the coil can be placed out of reach of the experimenter and only a switch placed within easy reach.

If a 10-inch coil is used, it will require a primary current of about 12 volts and 10 amperes to operate it to its full capacity. How to procure this current, either by primary or storage batteries or by the street mains, will depend on which are most easily procured or at hand. To describe in detail the various connections will not be necessary, as the maker of the coil usually provides such information.

46. The Contact-Breaker.—One point must be dwelt on more in detail, and that is the interrupter, or contact-breaker. It is important to know how to manipulate the latter so as to secure the best results, and for this reason the interrupter shown in Fig. 11 will be more fully described. The hammer *H* is attached to one extremity of the spring *S*, and is periodically attracted by the magnetized core of the coil. A post *P* carries the adjusting-screw *e*, and is connected with the positive pole of the battery; it will therefore send a current through the vibrating spring *S* whenever the two contact-pieces *c*, *c* either touch each other or very nearly do so; this spring connects with the primary coil and the condenser. The screw *T* engages with the bracket *R*, and has a collar *g* that bears against the spring; a bushing *b* of insulating material, through which the screw passes, prevents electrical communication between the latter and the post *P*. The interrupter is capable of regulation in two ways: (1) by turning the head *f* of screw *T* to the left, thereby increasing the pressure of the collar *g* on the spring; and (2) by turning the screw *e* so as to adjust the length of the sparks. The result in the first case is that it will take a stronger magnetic force to break connection between the contact-pieces *c*, *c*, and the vibrations of the spring will therefore be fewer in number. In the second case, the nut *d* serves simply as a locknut, to prevent the turning of *e*.

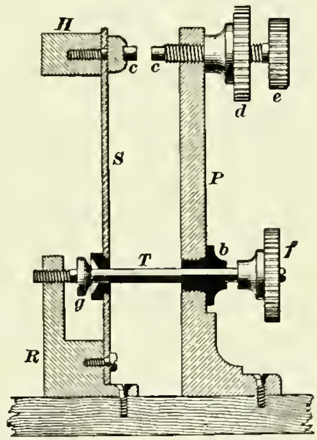

FIG. 11.

47. Starting the Coil.—When starting the coil, the screw *T* should be turned toward the right, so as to release the spring *S* and let the hammer go as far toward the core as it will go. Next, the contact *c* of screw *e* is brought so as to nearly touch that of the spring. When, now, the current is

switched on, the hammer will perhaps at first not vibrate; but, by turning the screw T so as to bring on more tension, the vibrations will soon begin. These at first will be quick and the sparks small, while perhaps the secondary coil will be inactive so far as sending any sparks between the discharge-rods is concerned. Continuing to increase the tension on the spring, the E. M. F. in the secondary coil will after a while be sufficient to send sparks across the air-gap. It is possible that the coil does not work at its best when the current passes through it in the present direction; it is therefore advisable at this stage to turn the commutator so as to reverse the current and see if the sparks are more profuse. That position of the commutator which seems to be the most advantageous for the coil is the one to be retained during its further use.

48. Increasing the E. M. F.—To further increase the E. M. F. in the secondary coil, the screw e is turned so as to bring it farther away from d, and the spring S still more tightened by means of the screw T; the distance between the contacts c, c should not exceed $\frac{1}{32}$ of an inch. By continuing the increase of tension on the spring, a point will soon be reached where its action will be very short and decisive. It will then send a very strong current through the coil, particularly if the contacts c, c have a gap between them of about $\frac{1}{16}$ inch; the volume of the spark is now great and the spark itself of long duration. Sparks of this character must only be used for a short length of time—say a couple of minutes—as it is dangerous for both the tube and the coil, and injurious to the platinum contacts. The spring S should be handled with care, as the whole action of the coil depends to a great extent on the quality of the spring. It should, therefore, as soon as the coil is put out of action, be released and not kept under a constant strain.

49. Constructive Details.—A few data relating to constructive details may here be of interest. The action of the condenser is ordinarily taken to be simply that of preventing sparking between the platinum contacts, and thus lengthen the service of the latter. This is not quite correct; it does prevent

sparking, but the result is twofold. Besides saving the platinum contacts, it makes the break of the current short and decisive by sending the extra current down in the condenser. We have already seen that the E. M. F. in the secondary depends greatly on the speed with which the magnetic lines of force of the primary cut through the secondary coil, and see from this the importance of a quickly interrupted current. Experiments with the condenser have shown that, if while a coil is working the former is disconnected, the sparks will no longer pass between the discharge-rods unless they are brought nearer together. With the condenser in circuit the sparking length was in one instance found to be 4 inches, but after removing the condenser the discharge-rods had to be brought within a distance of $\frac{1}{2}$ inch of each other.

50. Character of Current in Secondary.—Another peculiarity of the induction-coil is the character of the current in the secondary, as influenced by the condenser. We have seen in Art. **82**, Seetion 2, page 63, that the charge stored in the condenser has the effect, when discharging itself in opposition to the current from the battery, of still more increasing the effect of the break-current, by suddenly demagnetizing the core. In addition to this, it also tends to partly stop the current beginning to flow from the battery, when contact is again made, thus cutting down the effect of the make-current still more. The effect of increasing the difference between these inductive actions is to make the spark, produced in the secondary coil by the break-current, predominate to such an extent that when they have to overcome resistances such as met with in X-ray work, the break-spark alone will be able to pass; consequently, the current through the focus-tube will be a direct intermittent current of high voltage. In large coils having the discharge-rods so close together as to leave an air-gap of .04 inch only, and with a spring under low tension, the current will be alternating. In this instancc, the condenser action and the resistance is so small that the difference between the two induced currents is hardly perceptible. Regarding the length of the secondary coil

and its influence on the length of the sparks, it has been found that, in coils of medium size, producing 6-inch sparks, it takes about 6 or 7 miles of wire, or 1 mile for each inch of sparking-distance. For smaller coils, not quite so much wire will be needed.

TESLA COILS.

51. Construction and Operation.—It was explained in Art. **69**, Section 3, page 52, how the discharge of a circuit can be made oscillatory when the relation between the resistance, capacity, and self-induction of the circuit is such as to favor an oscillating discharge. In the Tesla coil this property is made use of and is attained by the insertion of Leyden jars in the circuit, and by utilizing the oscillating current derived from these for the operation of the primary coil of a supplementary induction-coil made of heavy wire of few turns and well insulated in oil. Fig. 12 is a diagrammatic view of a Tesla coil with its connections to a strong induction-coil. The induction-coil *A* may be excited by an ordinary alternating current, such as is to be had from the lighting circuits; the wires *w*, *w* connect the latter with the terminals *p*, *p* of the primary coil. The secondary terminals *e*, *f* have the ordinary discharge-rods *a*, *b*, and connect with the internal coatings of the Leyden jars *c*, *d*. The external coatings are connected to the primary terminals *g*, *h* of the Tesla coil *B*, and the tube *l* to its secondary terminals *i*, *k*.

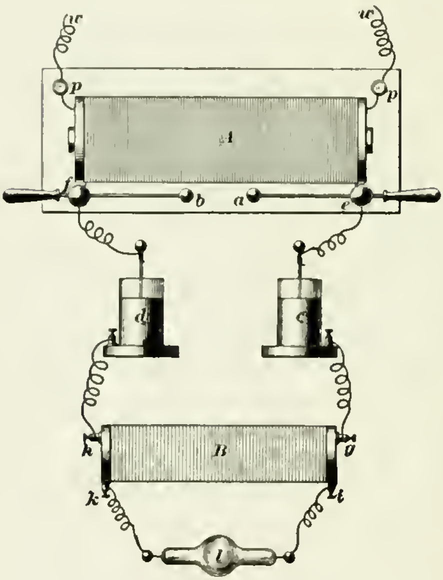

Fig. 12.

When a current is sent through the coil A, a spark will not pass between the rods a, b until the Leyden jars have been charged. The discharge of the latter is then oscillating, and their free outside charges will pass through the primary $g\,h$ of the coil B; while the E. M. F. thus produced in the secondary $i\,k$ is sending a current of very high E. M. F. and a frequency of several hundred cycles per second through the tube l. This frequency will depend on the capacity of the jars, and on the self-induction of the coil B. The latter consists, therefore, of rather few turns, which are wide apart and well insulated in oil.

52. Use of Tesla Coils.—The use of the Tesla coil is not limited to a combination with an ordinary induction-coil; it may also be used in connection with an influence-machine, when the whole arrangement is very similar to that of Fig. 12. The Leyden jars are then connected to the prime conductor in the same manner as shown in Fig. 9, the rest of the circuit remaining unchanged. This is a convenient method for producing most powerful X-rays of great penetrating power.

53. Means for Observing the X-Rays.—As the X-rays themselves are invisible, some means must be provided by which either their presence or their strength may be ascertained. It was already early observed that the X-rays were able to cause various substances to fluoresce. *Fluorescence* is said to exist when light-rays, otherwise invisible, are causing certain substances to emit light, showing thereby that light-waves, which originally were of so short a wave-length that the nerves of the human eye were unable to respond to their vibrations, were absorbed by certain substances and changed into waves of greater length. These longer waves were of sufficiently low frequency to be capable of being perceived by the eye. If these substances fail to emit light when the stimulating rays cease, they are said to be *fluorescent;* if they continue to give out light for hours and even for weeks afterwards, they are *phosphorescent.* In either case it is light produced without heat, and is therefore termed "cold" light.

54. Substances Used.—It will be unnecessary to here enumerate the various substances possessed of this property; we will therefore simply mention those that have shown themselves to be most serviceable for the present purpose. At first, platinocyanid of barium was used very extensively, and later, potassium platinocyanid; the first was inferior in brilliancy to the latter, but possessed more definition and would stand harder usage. The brilliancy of the barium crystals has since been much improved by recrystallization, by which process the crystals are gradually reduced in size, until they finally resemble mere powder in appearance. After experimenting with numerous substances, Edison found calcium tungstate to be the most satisfactory, and it is used most extensively in this country. It is made into a powder, and distributed over gummed paper, either black or blue, while the gum is still wet. Other substances, such as iodid of rubidium and double fluorid of uranium and ammonium, have also been used, and found to make excellent screens.

55. Fluoroscope.—This prepared paper may either be part of a screen—that is, the paper may be stretched over a frame large enough to take in the whole object under observation, and the frame made stationary—or it may be placed across the end of a pasteboard box formed something like a stereoscope. In the latter case it can be held in the hand and moved from one place to another, depending on the part to be observed. The latter device is called a *fluoroscope*, and has this advantage over the screen, that it may be used in daylight; while the room must be darkened, if the shadows on the screen are to be observed. That side of the screen which is covered with the florescent material must be turned toward the observer.

56. Advantage of Fluoroscope.—Observations made by means of the screen or fluoroscope have the advantage over investigations made by the aid of photographs, in that, in the former instance, the object under observation may be seen in motion, in case it is a part of a living organism. In this manner it is possible to study the action of the heart and other internal organs. Fractures, discolorations, and foreign bodies

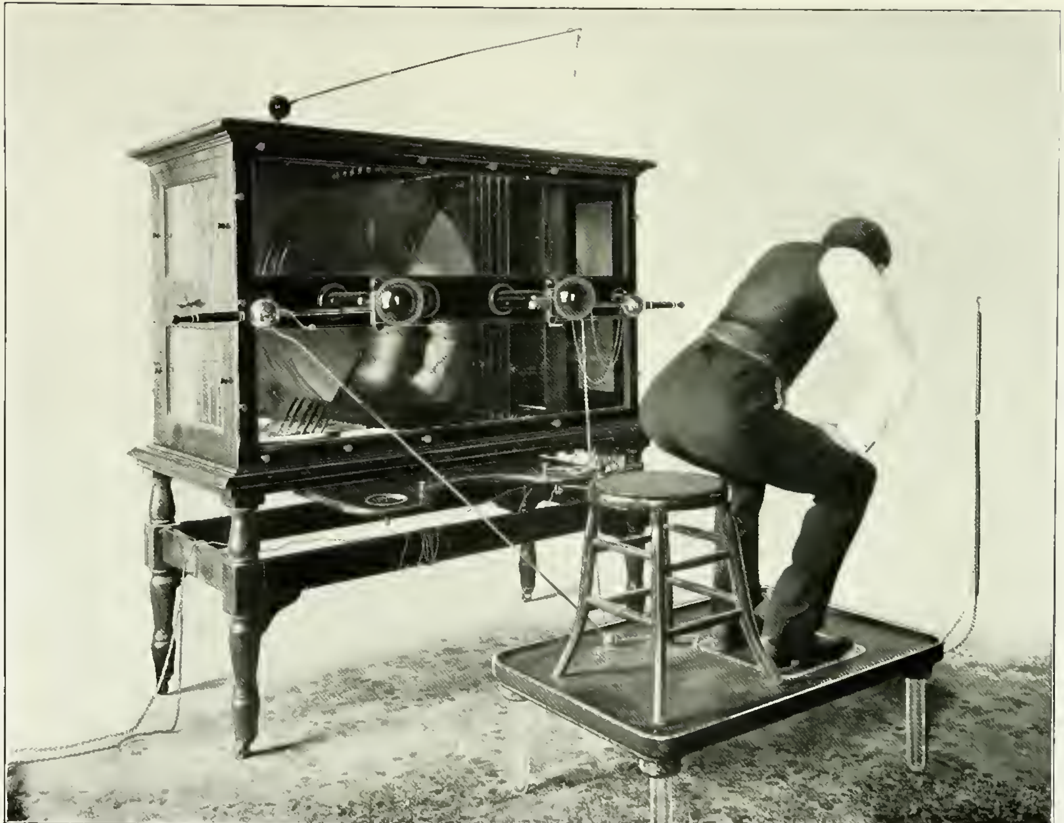

PLATE XXVIII

Posture in Treatment of Lumbago.

may be studied in many different relations with the fluoroscope. The advantage of this in diagnosis is obvious. It must not be supposed that such screens convert all the X-rays into fluorescent rays; on the contrary, a great amount of the former pass unaltered through, so that several screens may be placed one behind the other, and all be affected, but to a varying degree. This phenomenon causes some trouble when the attempt is made to photograph the image as it appears on the fluorescent screen, as will be seen further on.

RADIOGRAPHS, SCIAGRAPHS, AND PHOTOGRAPHS OF SCREEN AND IMAGES.

57. The image that appears on a fluorescent screen is only of a fleeting existence; as soon as the current is shut off it is gone. This is sufficiently long for preliminary investigations, but when it comes to the location of certain objects fractures, etc., the accurate knowledge of which is required for subsequent treatment, then it is of importance to have a permanent record of the screen image. This may be attained in two ways: either by letting the X-rays pass through the object and affect a photographic plate situated at the rear side, when we have what are called *radiographs*, or *sciagraphs;* or by throwing a shadow of the object on a fluorescent screen and photographing in the ordinary manner.

58. Arrangement of Tube and Plate.—How, in either of these cases, the tube and the plate are arranged to best advantage will depend on circumstances. One method has been shown in Fig. 9, and this is the usual way when the photographic plate is supported by a table. The main thing is that both the tube holder and the plate are firmly supported on a firmly standing table. It is also necessary that the object to be photographed, such as a hand, is so placed, relatively to the plate and the tube, that it will not shift its position. This is conveniently done by means of some strips of the adhesive plaster used by surgeons. When it comes to larger objects, then circumstances will decide which method

to pursue in order to retain the original position between plate and object. As for fastening the tube, it has been found convenient to insert the stem of the same in a piece of cork, and to have this grasped by the various-shaped holders. In this manner it can be more firmly supported, with less risk of being broken. The holder should be adjustable with a horizontal and perpendicular rod.

59. The Image.—Of course it will be understood, from what has been said about the nature of the X-rays, that, when an object is examined by means of a fluoroscope or a screen, the image observed is not a picture of the object—that is, it does not derive its existence from light rays *reflected* from its surface, as ordinarily is the case. On the contrary, it is produced by X-rays *penetrating* the object, and is therefore nothing but a shadow; and the various internal parts are shown, because they do not allow as much light to pass as some of the surrounding parts, and therefore appear darker and stand out on a lighter background. As this shadow is produced by rays proceeding in straight lines from the anode or the anticathode, its sharp definition will depend on the fulfilment of certain conditions. If the radiating part of the anode were a point only, the rays would produce shadows of sharp, distinct outlines. As this part is not a point when the cathode is flat or slightly curved, but rather more like a surface, and therefore, so to say, a collection of points, it follows as a consequence that each of these points tends to produce a shadow of its own, and that therefore the various shadows will be superimposed on one another, with each individual shadow somewhat overlapping that of its neighbor. The shadow as a whole, therefore, will not have clear and well-defined outlines, but will be more of a diffused nature.

60. To Obtain Well-Defined Images.—To obviate this, two different ways may be pursued: (1) the distance between the object and the tube may be increased; or (2) the radiating part in the tube may be reduced to a point. The first of these methods will bring the object out of reach of some of the rays, at the same time as the effect of the remaining rays will be

diminished by the increased distance; in fact, the effect of the X-rays will decrease in direct proportion to the square of the distance, and will therefore require a longer exposure of the photographic plate. The reduction of the radiating surface is attained in the focus-tube by means of the cup-shaped cathode. Thus, the attainment of sharp outlines seems to be a relatively simple matter so long as we have to deal with objects, the dimensions of which in the direction of the rays are small; but when we come to such objects as the trunk of the human body, we have to deal with more complicated conditions.

61. These conditions may be better understood by comparing them with those existing while an object is under examination under a microscope. Fig. 13 shows an object *A* resting on a glass plate *d*. It is a known fact that microscopes of high power will allow only those parts lying in one plane at right angles to the axis of the objective to be examined simultaneously. Thus, while the microscope is focused on the ring *a* in the figure, nothing can be seen existing above or below, except a certain diffused light. In the same manner, when the other rings *b* and *c* are brought in focus, only one ring is visible at a time.

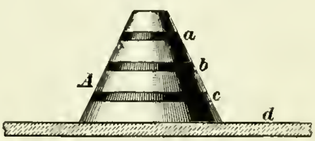

FIG. 13.

62. Outlining the Internal Organs.—The action of the X-rays in outlining the internal organs of the human body is very similar to this. It was shown that objects placed near the tube throw somewhat diffused shadows, and to be fairly well defined should be at a distance from the tube of about 9 or 10 inches, if they have a thickness corresponding to that of the human hand. Should the human body be placed at a distance proportionate to that of the hand, it would be so far away that all parts would appear with equal distinctness. But would this be a desirable picture? Leaving out of consideration the fact that it would require an inconveniently long exposure, the image would have the various parts lying in separate planes superimposed on one another in one confusing mass. It is

therefore obvious that it is preferable to picture each part separately, and it will have to be decided beforehand which part is wanted and how best to show this part in clear outlines, without being confused by any adjacent structures.

63. Photographing Bony Structures.—Here we proceed in a manner very similar to that followed in using the microscope, as seen in Fig. 13, with the additional requirement that the object in question shall be as near the photographic plate as possible. We then bring those parts not required in the picture as near the focus-tube as possible, while the photographic plate is placed near the parts that have to show most clearly. If, for instance, the spine is to be photographed, then the chest is brought to face the tube, and the sensitive-plate is placed close to the spine. Everything in front of the latter will then be exposed to diffused rays, and will, to a great extent, disappear, while the spine will be defined in clear outlines. Should the front of the trunk be required, then of course the procedure is reversed.

64. Photographing Muscles.—When we have to deal with bony structures alone, this method will serve the purpose very well, but to define parts made up of other substances, such as the internal organs, we have to seek some additional means to make a greater distinction between them and other adjoining structures. To show the muscular part of the hand, for instance, does not present so many difficulties. It is only a question of using rays of less penetrating power, such as may be obtained by a tube with less vacuum and a small current. With a depth as possessed by the trunk of the human body, a tube of low vacuum would not do, because unable to penetrate the body, and here both a high-vacuum tube and a powerful current will be required. In cases of this nature it seems advisable to place the object as far away from the tube as possible, and use long exposures, with a subsequent slow development and intensification. In some instances, matters may be simplified by the use of a plate of lead; the latter is rather impervious to X-rays, and by holding it over parts requiring less exposure, while moving it to and fro, it will

PLATE XXIX.

End View of Static Machine, Showing Rheostat a, Having Twenty-Five Buttons, Each Button Representing Five Ohms.

somewhat counteract the effects of the rays. It has also been found that, by exposing several plates simultaneously, one behind the other, one plate will reduce the strength of the rays reaching the next plate, so that, if one plate is over-exposed, one of the adjoining ones may have obtained a correct exposure and show the objects clearly outlined.

65. Difference Between Fast and Slow Plates.—It has been stated by some experimenters that it makes no difference whether a photographic plate is fast or slow: the results are the same. While the difference is not so marked as when used for ordinary work, still there is a difference, though in some special cases the slow plate may be the faster. It is often important to have the exposures short, and various means have been proposed for this purpose. One method, which in many cases has been found quite useful, is to place a small fluorescent screen in close proximity to the plate. If this screen is put in front of the plate and in contact with it, the rays will first have to travel through the screen, and the resulting radiograph will be somewhat diffused. This is caused by the fact that the crystals on the screen are not small enough, and therefore will picture a straight line as a ragged one. A reversal of the arrangement is better; then the back of the plate is turned toward the object and the film is placed in contact with the screen. In this instance, the rays travel through the glass and film before they reach the screen. The outlines are therefore produced by the rays themselves, while the screen reflects the light received through the glass.

66. Use of Fluorescent Screen.—Objects exposed to X-rays cannot be photographed by means of an ordinary camera: it is only by the interposition of a fluorescent screen that this can be done, and then it is no longer the X-rays that are visible, but ordinary light. When the image that appears on a fluorescent screen is to be photographed by letting the visible light pass through the lens, there are certain precautions that must be taken in order to insure a successful picture. Take, for instance, the case of a person standing upright between a focus-tube and a screen and in close proximity to the

latter, for the purpose of having his spine photographed. An image of the spine is seen on the fluorescent screen, and it is desired to make an enlarged or reduced copy of the said image by means of the camera-lens. To do this, the latter will have to be in direct line with the X-rays emanating from the focus-tube; and, as it was shown that the fluorescent screen does not absorb all the rays and transform them into visible rays, a certain portion will of necessity reach the camera. These rays would, in passing through the camera front, throw a shadow of its metallic parts on the sensitive-plate in addition to the image from the fluorescent screen. In the resulting photograph there would consequently be various figures not belonging there that would cause confusion. To avoid this, it is customary to cover the front of the camera with a plate of lead, and to leave an opening that is only large enough to permit the light-rays from the lens to pass through. Lead being very nearly impervious to X-rays will prevent any rays from reaching the sensitive-plate except through the lens.

67. Development of Plates.—To enter into details concerning the exposure and development of sensitive-plates and their subsequent intensification will not be necessary. Manufacturers of cameras and plates usually give detailed information on these points, and the additional information needed in this line can only be acquired by actual experience. It is, however, recommended that the physician develop his own plates, because the knowledge gained in this way will be of service to him. The negative forms the best record of a case for immediate examination or for future reference. The time required for developing a plate is usually short. Both the time and the trouble will be amply compensated for by the knowledge acquired in studying details as they appear.

TECHNIQUE

AND

PHYSIOLOGY OF STATIC CURRENTS.

Technique and Physiology of Static Currents

---

(1) Into what forms of energy is electricity transformed when applied to the human body?

(2) Has the static current any electrolytic or cataphoric action?

(3) In what does the action of static currents mostly consist?

(4) What static machine is now in most general use?

(5) What was formerly the chief drawback to the popularity of the static machine, and how was this overcome?

(6) What are the connections necessary for applying positive sparks in Experiment 1?

(7) (*a*) How are the breeze and spray made bland and sedative in Experiment 2? (*b*) How counter-irritant?

(8) In applying the counter-irritant spray, why is the positive pole connected to the platform?

(9) What is the difference in the effects produced by using groundings in one experiment and not using them in the other?

(10) What is the technique of arrangement for potential alternation?

(11) What is gained by grounding the fixed electrode?

(12) Explain the construction of the Wimshurst machine.

(13) What are the usual methods of operating the Holtz induction-machine?

(14) State briefly the best means of keeping the interior of the case dry.

(15) How often should the calcium chlorid be baked?

(16) What is the indication for rebaking?

(17) Besides rebaking the calcium chlorid, give some other means by which the efficiency of the static machine may be increased during the sultry days of summer.

(18) (*a*) Describe the method of grounding the poles and electrodes. (*b*) What advantage is derived from two separate groundings?

(19) Describe the essential points in the grounding of the prime conductors and electrodes.

(20) What is the best means of procuring high-potential difference between the two static poles?

(21) Describe the platform now in general use.

(22) Give the dimensions of the platform.

(23) At what distance should the platform be placed from the prime conductors and from the office furniture?

(24) Why is it necessary to move the platform some distance from the negative pole during positive electrification?

(25) (*a*) How many methods are there for conducting the current from the prime conductors to the patient? (*b*) What do you understand by direct conduction?

(26) (*a*) In how many ways may the current be conducted to the patient by the direct method? (*b*) Describe them.

(27) (*a*) State briefly how current-leakage between the prime conductor and the patient may be detected, and the amount in a general way measured. (*b*) What does this prove?

(28) What three methods are there for distinguishing the polarity of the machine?

(29) (*a*) How is the initial charge communicated to the Holtz induction-machine? (*b*) Explain the method fully.

(30) How is the Holtz induction-machine discharged?

(31) (*a*) What is reversed polarity? (*b*) How may it be corrected?

(32) Give some advantages of static applications over those made by the galvanic and faradic currents.

(33) What constitutes the basis of all static treatment?

(34) (*a*) What is absolutely necessary in order to employ static currents therapeutically? (*b*) How is this necessity procured?

(35) How can you verify the fact that accumulation is necessary?

(36) Describe the technique for simple positive electrification.

(37) How does the value of positive electrification as a therapeutic agent compare with negative electrification?

(38) What can you say in general about positive electrification?

(39) Why should conversation be prohibited during the séance?

(40) What are the connections necessary for negative electrification?

(41) What is positive and negative electrification generally termed?

(42) What effect is produced by interrupting the current in potential alternation?

(43) How are the patient's feet protected from sparks?

(44) Describe the different methods of interrupting the current between the patient and the prime conductor.

(45) What are the effects of potential alternation?

(46) By whom and when was potential alternation first described?

(47) Describe the technique for exercising the muscles of the arm and forearm by potential alternation.

(48) During a local treatment, is the region to which the current is applied the only part benefited?

(49) What are some main points of difference between static treatments and galvanic and faradic treatments?

(50) State the local static methods in the order of their therapeutic properties.

(51) On what does the intensity of the static breeze and spray depend?

(52) Describe the method of administering the positive breeze.

(53) In how many ways may the breeze be administered?

(54) (*a*) How is the movable breeze administered? (*b*) How is the stationary breeze administered?

(55) Describe the method of administering the continuous and interrupted breeze.

(56) (*a*) State the effects of the positive breeze. (*b*) What are the indications for this form of treatment?

(57) In what does the technique of the negative breeze differ from that of the positive?

(58) What effect has resistances on parts treated by the negative breeze?

(59) How can the negative breeze be made counter-irritant?

(60) What conditions are benefited by the negative breeze?

(61) (*a*) Define breeze and spray. (*b*) What is the difference between them?

(62) Why must care be taken in using the positive breeze?

(63) What form of treatment is indicated for asthma and bronchitis?

(64) How may this treatment be made more efficacious?

(65) Describe the technique of the negative spray applied to the joints.

(66) How are sparks given?

(67) What electrodes are used in spark treatment?

(68) How many kinds of sparks are there?

(69) How may sparks be given by the brass-pointed electrode?

(70) What is the length (*a*) of the percussive spark? (*b*) of the frictional spark?

(71) As generally used, what is the action of frictional sparks?

(72) (*a*) In static methods, how many forms of kinetic energy are there? (*b*) Describe them.

(73) State clearly the different methods of increasing and decreasing the energy of static applications.

(74) (*a*) Which do you consider the poorest method of conducting the current from the prime conductor to the patient? (*b*) Which is the best method?

(75) Describe the action of the spark when applied to the human body.

(76) What argument can you advance to prove that static currents penetrate the body?

(77) Describe the method of administering the breeze, spray, and spark with the brass-pointed electrode.

(78) Do you know of any rule applicable to all forms of spark treatment?

(79) What is the difference in the sensory effects between short thick sparks and long thin ones?

(80) What electrode is used in spark treatment to the neck and perineum?

(81) When using the brass-ball electrode, what precautions are necessary to prevent sparks from flying to the various parts of the face?

(82) (*a*) With the same platform connections and with the same motion of plates, describe the difference in the sensory effects between the negative and the positive spark. (*b*) To what do you attribute the difference?

(83) (*a*) What effect have air-spaces on sparks? (*b*) How are they avoided?

(84) What is the effect of damp clothing on spark treatment?

(85) What two objects should be kept constantly in view in every static treatment?

(86) As a rule, what parts of the body should be avoided in spark treatment?

(87) Describe the technique of positive friction to the spine, or to any part of the body where it may be indicated.

(88) What is the most efficient method of applying the spray?

(89) Give some of the indications (*a*) for the use of the long percussive spark; (*b*) for the use of the short frictional spark.

(90) What can you say about the spark as a tonic and alterative?

(91) How is the mildest spark administered?

(92) How are frictional sparks administered?

(93) What governs the length of the frictional spark?

(94) What is the best method of procedure in applying frictional sparks?

(95) In giving any form of treatment, what is the main point to be guarded against?

(96) On what parts of the body should sparks be first given?

(97) Which of the local static methods do you consider the most effective?

(98) Describe postural treatment and its advantages.

(99) (*a*) Describe the static cage. (*b*) Explain the methods of using it.

(100) If the current is interrupted while using the static cage, how are annoying sparks to the patient's feet prevented?

(101) What are the indications for using the static cage?

(102) How is the massage-roller used?

(103) (*a*) Describe both methods of massage-roller applications. (*b*) What are the effects produced? (*c*) What regulates the dosage when using the roller?

(104) (*a*) What are Leyden jar currents? (*b*) How are the Leyden jars connected to the prime conductor?

(105) Describe fully the technique of applying Leyden jar currents to the larynx and to the muscles of the forearm.

(106) (*a*) What is the nature of Leyden jar currents? (*b*) How is dosage regulated?

(107) How are Leyden jar currents applied to the lower extremities?

(108) Describe the technique for using the foot-bath with Leyden jar currents.

(109) What is the difference between the effects produced by the use of Leyden jar currents and coil-currents?

(110) How is the current interrupted in using Leyden jar currents?

(111) How are the interruptions made slow and rapid?

(112) (*a*) What effect have slow interruptions on the muscles? (*b*) What effect have rapid interruptions on the muscles?

(113) What is the function of Leyden jars?

(114) What is the difference in the current in the three sizes of Leyden jars used with the static machine?

(115) What are the main uses of Leyden jars?

(116) What conditions are better treated by coil-currents than by Leyden jar currents?

(117) (*a*) Before starting the static induced current in action, what should be the position of the poles? (*b*) How is the current then regulated?

(118) Can you produce the same physiological action with the large Leyden jars that you can with the small ones?

(119) How can the sedative properties of the long fine-wire coil of a scientifically constructed coil-battery be obtained by using Leyden jar currents?

(120) How can the effects of the medium-wire coil of the induction-apparatus be obtained by using Leyden jar currents?

(121) How can the effects of the coarse-wire coil of the induction-apparatus be obtained by using Leyden jar currents?

(122) In what class of diseases are Leyden jar currents contraindicated, and why?

(123) What advantages has a scientifically constructed coil-battery over Leyden jar currents?

(124) Describe the physiological action of Leyden jar currents.

(125) What is the electrical condition of the air in malarial districts?

(126) In the treatment of malarial conditions, which electrification would you employ?

(127) State the chief difference between the two poles of the static machine.

(128) What is the chief difference between the effects produced by breeze, spray, and spark?

(129) If the patient's apparel is silk or cotton, in what position would you manipulate the electrode in order to obtain the best results in breeze applications?

(130) What would be the effect of spray applications through woolen garments of loose texture?

(131) How are the irritating effects of the breeze modified?

(132) What is the usual length (*a*) of séances in static treatment? (*b*) of stimulating applications? (*c*) of sedative applications? (*d*) of counter-irritant applications?

(133) State some differences between the action of Leyden jar currents and the action of a scientifically constructed coil-apparatus.

(134) In what part of the body is this difference most manifest?

(135) State briefly the action of static currents on the human organism.

(136) (*a*) What is the chief action of static currents? (*b*) How has this action been determined?

(137) What effects have static currents on (*a*) the temperature? (*b*) the pulse? (*c*) the respiration? (*d*) absorption? (*e*) secretion?

(138) What effect has static treatment on healthy organs and normal functions?

(139) What are the great fields for the use of static currents?

(140) What is the chief characteristic of static electricity?

(141) Is the action of static electricity simply on the surface of the human body?

(142) Where and how did the theory of surface action originate?

(143) What is the effect of static sparks on molecular combinations?

(144) What effect have static sparks on nutrition, local and general?

(145) How do you explain the therapeutic results of counter-irritation?

(146) Give a brief summary of modern opinion on the action of static currents.

(147) Why should Leyden jars be used with great care?

(148) What form of static technique is best when treating a nervous patient for the first time?

(149) Why is it always advisable to begin with the simplest and mildest forms of treatment?

(150) In how many ways may the current be interrupted between the prime conductor and the patient?

(151) What great advantage has the static current over other currents in general treatment?

(152) Why is the calcium chlorid placed in the case of the static machine?

(153) How is the mildest static spark administered?

(154) Enumerate the methods by which the strength of the static current is (*a*) increased; (*b*) decreased.

(155) What precaution is necessary when handling the fixed electrode when the long spark is delivered?

(156) What is the usual length of spark-gap in potential alternation?

(157) How is the dose regulated in this form of treatment?

(158) How are less than one hundred interruptions a minute best obtained when using Leyden jar currents?

(159) On what does the systemic action of static electrification depend?

(160) What is the predominant action of static currents on the human organism?

(161) (*a*) Has the static machine any fixed voltage? (*b*) How is its voltage regulated?

(162) What can you say about the spark as a tonic and alterative?

(163) Describe the technique of the Franklinic interrupted current.

(164) In using the induced current, where is the current interrupted?

(165) When the interrupter is in circuit with the patient. what is the nature of the current that the patient receives?

(166) What is the nature of the current when the interruption is in the primary circuit and the patient is in the secondary circuit. the external coating of the Leyden jars not being connected?

(167) (*a*) Why cannot the bipolar vaginal electrode be used with the induced current? (*b*) What kind of electrodes are used with the static induced current?

(168) (*a*) Describe the primary circuit of the induced current. (*b*) What is the function of the discharge-rods in this case?

(169) How may the noise caused by the sparks passing between the discharge-rods be obviated?

(170) How may the current be regulated when using the static induced current?

(171) If the small machine that is enclosed in the same case with the Holtz machine and serves to communicate to the Holtz machine an initial charge should lose its charge, how is it recharged?

(172) When not in use, where is the proper place for Leyden jars?

(173) What difference is there, if any, between Leyden jar currents and static induced currents?

(174) In what other line of medical and surgical work, other than in the therapeutic applications, is the static machine the best source of electrical energy?

(175) What determines the name of the static application in local methods?

Physiology

of

Direct Currents.

Physiology of Direct Currents.

(1) On what do the therapeutic uses of the direct current depend?

(2) What dominates the application of direct currents to the human organism?

(3) Define a voltaic alternative.

(4) Why is a voltaic alternative the strongest electric neuromuscular stimulus?

(5) When regeneration of an injured or diseased nerve occurs, how is its trophic activity first manifested?

(6) What is the chief obstacle to the passage of direct currents through the body?

(7) When a direct current is passing through the body, does the resistance of the body decrease or increase?

(8) Why is the coil-current always used first in electro-diagnosis?

(9) How did Dubois-Raymond demonstrate the existence of electric currents in nerves and muscles?

(10) What did Dubois-Raymond consider the source or origin of electric currents in the nerves and muscles?

(11) State the theory advanced by Herman.

(12) What is meant by (*a*) the current of rest? (*b*) the current of action?

(13) Define a polarizing current.

(14) What effects are produced by the continuous passage of the direct current through a motor nerve?

(15) Why did Dubois-Raymond use non-polarizing electrodes?

(16) Does the continuous passage of a direct current through a motor nerve contract the muscles to which it is distributed?

(17) What is necessary to produce muscular contraction by the direct current applied to a motor nerve?

(18) Describe the effect of the continuous passage of the direct current through a muscle.

(19) What determines muscular contraction when a nerve is stimulated?

(20) Define (*a*) electrotonus; (*b*) anelectrotonus; (*c*) catelectrotonus.

(21) What is the most probable cause of the changed irritability of a nerve when it is carrying an electric current?

(22) When is a nerve said to be stimulated?

(23) By what two means is the nerve stimulated by the direct current?

(24) Which of these means is the more stimulating?

(25) State Pfluger's laws.

(26) What is the condition of the nerve called when a current is passing through it?

(27) (*a*) What is the condition of the nerve immediately beneath the cathode called? (*b*) What is the condition immediately beneath the anode called?

(28) In a nerve in the human body, why does not the whole current flow through the nerve from anode to cathode?

(29) In testing the electrical reactions of the motor nerves of man, what apparatus is required?

(30) Give the normal polar formula for a motor nerve.

(31) What current-strengths are required to produce these contractions?

(32) State the law of current-density.

(33) (*a*) Why is the cathodic closing contraction strongest? (*b*) Why is the cathodic opening contraction weakest?

(34) What is the neuromuscular effect of the make-and-break current of the induction-coil?

(35) State the difference in the effects produced by the slowly and rapidly interrupted coil-currents.

(36) How is the current-strength measured when using the faradic current to explore motor nerves?

(37) With a rheostat in the primary and secondary circuits, how may the current-strength be determined?

(38) What effects are produced by applying direct currents to nerves of special sense?

(39) How may the distribution of sensory nerves be mapped out?

(40) Describe fully the effects produced by stimulating the optic nerve.

(41) What is the normal polar formula for the auditory nerve?

(42) Why is it that the auditory nerve does not give the same response to electrical stimulation as the optic nerve?

(43) What justifies a favorable prognosis in the use of electric currents in tinnitus aurium?

(44) With an electrode placed on each cheek, how may polarity be distinguished?

(45) In stimulating the olfactory nerve, what sensation is produced?

(46) In making applications of electricity to the head, what precautions are necessary?

(47) Describe the effects produced by galvanic and faradic applications to the brain.

(48) Is vertigo produced when both electrodes are applied to the same half of the brain?

(49) Describe the effects produced by the galvanic current applied to the spinal cord.

(50) How do non-striated muscles respond to electrical stimulation?

(51) What is the best means of stimulating non-striated muscles?

(52) State the characteristic of the reaction of non-striated muscles.

(53) How are the muscle-fibers of the intestines stimulated?

(54) In unilateral diseases, what method is followed in electrodiagnosis?

(55) What is the method of procedure in bilateral diseases of nerves and muscles?

(56) What nerves are taken as the standards of comparison when the disease is bilateral?

(57) What should be the size of the active electrode?

(58) Whose electrode is generally used?

(59) What is the size of the dispersing electrode?

(60) What can be determined by the help of direct currents in electrodiagnosis?

(61) In what two ways may the irritability of a nerve to the galvanic and faradic currents be altered?

(62) (*a*) When is the irritability of a nerve diminished? (*b*) When is it increased?

(63) Mention some diseases in which nerve irritability is (*a*) increased· (*b*) decreased.

(64) What are the qualitative alterations of muscle irritability?

(65) How does the faradic current contract muscles?

(66) Describe the reaction of degeneration.

(67) What are serial and modal changes?

(68) What is the chief phenomenon in reaction of degeneration?

(69) Name the electric currents in the order of their diagnostic importance.

(70) What does the presence of reaction of degeneration determine?

(71) State briefly the diagnostic and prognostic significance of reaction of degeneration.

(72) What diseases does the presence of reaction of degeneration exclude?

(73) What aid does reaction of degeneration give in forming a prognosis?

(74) In the disappearance of electronervous excitability, which is the last contraction to disappear?

(75) (*a*) To what is the prolonged, sluggish contraction of reaction of degeneration due? (*b*) How is this proved?

(76) Describe the pathological changes that take place in nerves and muscles during the existence of reaction of degeneration.

(77) State the diagnostic uses of electric currents in female pelvic diseases.

(78) What resemblance is there between motor nerves and the secondary wire of the induction-coil?

(79) How are the best therapeutic effects produced by the direct current?

(80) What is the diameter of the active electrode used for testing the irritability of nerve-trunks?

(81) Is a muscle *per se* capable of responding to electrical stimuli by contraction?

(82) In an animal poisoned by curare, do the muscles respond to electrical stimuli?

(83) Which is the most effective method of producing contractions in non-striated muscles?

(84) When are the size and the position of the dispersing electrode right?

(85) What knowledge is absolutely necessary in electro-diagnosis?

(86) What are the properties of the direct current?

(87) Describe the following properties of the direct current: (*a*) The physical properties; (*b*) the physiological properties; (*c*) the chemical properties.

(88) What can you say regarding the effects of steady and alternating magnetic fields on metabolism of tissues?

(89) What properties of the direct current are most used in medicine and surgery?

(90) Describe the experiments of Doctor Peterson and Mr. Kennelly, and state the results obtained.

(91) Describe the experiments of Professor Herdman.

(92) What is the essential difference between the experiments of Doctor Peterson and Mr. Kennelly and those of Professor Herdman?

(93) Define electrolysis.

(94) What is an electrolyte?

(95) What is the difference between electrolysis and galvanocauterization?

(96) What are the three factors to be considered in electrolysis?

(97) What do you understand by the following factors in electrolysis: (*a*) The physical factor? (*b*) the chemical factor? (*c*) the physiological factor?

(98) Why is it impossible to produce an entirely isolated action of the poles in any nerve of the human body?

(99) How much time may elapse before the galvanic irritability of the human nerve entirely disappears?

(100) With what are the phenomena of reaction of degeneration intimately connected?

(101) Give the Grotthuss theory of primary electrolysis.

(102) When electrolysis alone is desired, what must be the composition of the positive pole?

(103) Describe the electrolytic action of (*a*) the positive pole; (*b*) the negative pole.

(104) How can it be proved that the chemical action is the same in all parts of a circuit?

(105) How can electrolysis of animal tissues be best studied?

(106) (*a*) What was the appearance of the positive copper electrode that was inserted in a piece of butcher's beef after passing a current through it? (*b*) Describe the appearance of the negative electrode in this experiment.

(107) What acids are formed at the positive pole?

(108) Describe the reactions that take place at (*a*) the anode; (*b*) the cathode.

(109) What alkalis collect at the cathode?

(110) How may the action of the anode be made antiseptic?

(111) To what is the antiseptic action of the anode due?

(112) What is the difference in the eschar produced by the anode and that produced by the cathode?

(113) On what does the electrolytic action of the current depend?

(114) At which electrode does the visible action extend farthest?

(115) Describe the interpolar action of electrolysis.

(116) How can the polarization of human tissues be demonstrated?

(117) What is necessary before polarization of the tissues can take place?

(118) Explain the mechanical action of hydrogen on the tissues.

(119) What relation does the physical factor of electrolysis bear to the chemical factor?

(120) Define cataphoresis.

(121) How is the cataphoric action demonstrated?

(122) What is the direction taken by substances introduced into the body?

(123) On what does the amount of cataphoresis depend?

(124) How may complete anesthesia be produced by cataphoresis?

(125) Describe the electrodes used for galvanococain anesthesia.

(126) How can galvanococain anesthesia be made sufficient for the operations of minor surgery?

(127) Describe the method of procedure for anesthesia by solutions of guaiacol and cocain.

(128) State the advantages of guaiacol and cocain solutions over aqueous solutions of cocain.

(129) What is the supposed action of guaiacol?

(130) Describe the method of anesthetizing sensitive dentin.

(131) Describe the method of anesthetizing the gums.

(132) Why is it wrong to apply both the positive and the negative electrode to the gums to be operated on?

(133) Describe the positive electrode now in use in anesthetizing the gums.

(134) What is the strength of the cocain solution used (*a*) for the gums? (*b*) for sensitive dentin?

(135) What can you say about the surface area of the positive eleetrode and the area of the tissue to be anesthetized?

(136) What objection is there to guaiacol in dental work?

(137) State the current-strength and time required in anesthetizing sensitive dentin.

(138) Describe the method of bleaching teeth by cataphoresis.

(139) What solution is employed for bleaching teeth, and how is it prepared?

(140) Describe the method of sterilizing dentinal tissue, and state what substances are used for this purpose.

(141) (*a*) How many methods are there for the introduction of medicaments into the body by eataphoresis? (*b*) Describe them.

(142) What name has Dr. W. J. Morton given to these methods?

(143) Describe metallic electrolysis.

(144) Describe the action that takes place at the positive pole when a soluble electrode is used.

(145) In metallic electrolysis, how is adhesion of the electrode to the surrounding tissues prevented?

(146) Should adhesion occur, how is the electrode freed?

(147) Describe the method of acting on deeper tissues by metallic electrolysis.

(148) What is the current-strength used in metallic electrolysis?

(149) Describe the experiments used by G. N. Stewart in demonstrating the cataphoric action of the direct current.

(150) What electrodes are commonly employed in metallic electrolysis?

(151) When the action of the current alone is required, what should be the composition of the positive electrode?

(152) What non-oxidizable metal is generally used?

(153) What is the difference between electrolysis and cataphoresis?

(154) What determines the choice of poles?

(155) Describe the properties of (*a*) the positive pole; (*b*) the negative pole.

(156) Describe the difference between simple cataphoresis and metallic diffusion.

(157) What did Remak understand by the term *catalysis?*

(158) What is meant by cataphoric demedication?

(159) Mention some drugs introduced into the tissues from the area of the negative pole.

(160) What are the distinguishing features in the technique of metallic electrolysis?

(161) On what two factors does the loss in weight of the soluble electrode depend?

(162) By virtue of what process is an electric current conducted through organic tissue?

(163) Describe the action of the direct current on the skin.

(164) Is reaction of degeneration ever of more favorable prognosis than normal reactions?

Physiology of Alternating Currents and Hydro-Electric Methods.

Physiology of Alternating Currents

AND

Hydro-Electric Methods.

---

(1) What are the dominating qualities of coil-currents?

(2) What is the character of the effects produced by the faradic current?

(3) State the main points of difference in the volume and pressure of the three currents employed in medicine and surgery.

(4) What is the nature of the faradic current used in present medical practice?

(5) Name the essential factors in the formation of a faradic battery.

(6) What cell is mostly used to operate the induction-coil?

(7) What is the nature of the current in the primary coil?

(8) What should be the rate of vibration to give the muscle time to rest between contractions?

(9) What should be the rate of vibration to produce muscular massage?

(10) What should be the rate of vibration to produce sedation?

(11) At about what number of vibrations per minute do excitant effects cease and sedative effects begin?

(12) What are the advantages of two adjustable vibrators?

(13) Describe Dr. Goelet's battery.

(14) Why is its secondary coil made up of different lengths and sizes of wire?

(15) What is the special advantage of Doctor Monell's battery over other induction-apparatus?

(16) Describe the rheostat used with Doctor Monell's battery.

(17) Describe the advantages of a scaled rheostat in the patient's circuit.

(18) Name the methods by which the quality of the interruptions of the induction-coil may be tested.

(19) Describe the method of determining the length and sectional area of a coil.

(20) How may the E. M. F. of any coil be tested?

(21) How may the polarity of the induced current be determined?

(22) State why the current from the fine-wire coil is sedative.

(23) State why the current from the short coarse-wire coil is stimulating.

(24) Describe the physiological effects on muscles of slow and rapid interruptions.

(25) On what does the effect of the rapidly interrupted coil-current depend?

(26) State Doctor Goelet's theory of the production of sedation by the current from the long fine-wire coil.

(27) How does Doctor Apostoli explain the effects of the rapidly interrupted current?

(28) Describe the method and effects produced in the treatment of spasmodic and hysterical contractions by faradic currents.

(29) What diseases are most amenable to high-tension induction-coil currents?

(30) With both electrodes applied to the skin, and a low E. M. F., what are the effects produced (*a*) with rapid interruptions? (*b*) with slow interruptions?

(31) Describe the physiological effects of currents of high potential and high frequency on tissue metabolism.

(32) What is the first effect noticed on the patient submitted to these currents for about 15 minutes daily?

(33) Is the physiological action of induction-coil currents due to electromechanical or electrochemical action?

(34) In pelvic diseases, why is the bipolar electrode used?

(35) Describe the method of procedure in making electrical applications to the uterus and vagina.

(36) What is the special use of the current from the coarse-wire coil in pelvic diseases?

(37) What is the chief pelvic effect of the current from the long fine-wire coil?

(38) What should be the duration of the séance to produce sedation?

(39) When massage effects in pelvic diseases are required, what is the length of the séance?

(40) When it is desired to act on the pelvic circulation, what method is used and why?

(41) State the principal facts to be remembered in applying coil-currents in pelvic maladies.

(42) State the three different periodic induced currents, and describe their qualities.

(43) Which of these currents is best adapted to therapeutic uses?

(44) On what does the stimulating effect of the periodic induced current depend?

(45) On what does the stimulating property of the alternating current depend?

(46) How is the E. M. F. of the alternating current regulated?

(47) On what does the stimulating property of the static induced current depend?

(48) What similarity exists between static induced currents and the induction-coil current?

(49) Why is the current from the fine-wire coil used to produce sedation?

(50) What are the most important effects produced by coil-currents?

(51) How can the acceleration of functional activity of organs be demonstrated?

(52) How do alternating currents stimulate (*a*) the capillary circulation? (*b*) the lymphatic circulation?

(53) How is the relief of pain produced by the application of alternating currents?

(54) In stimulating applications, what is the length of the séance?

(55) To produce the best results by sedative applications, when should they be given?

(56 What current gives the best results in pelvic maladies?

(57) When pelvic disease is so far advanced as to make a radical operation necessary, of what use is the coil-current?

(58) With electrodes of equal size, at which pole are the muscular contractions more manifest with all variations of E. M. F.?

(59) How can muscles be restfully exercised?

(60) How would you remove fatigue or pain caused by too vigorous or too long faradic applications?

(61) What factors are given in a clinical record of direct-current applications?

(62) In describing coil-current applications, what factors are involved?

(63) What has been the usual means of regulating the current-strength in coil-current applications?

(64) What two resistances are to be taken into consideration in coil-current applications?

(65) Describe Doctor Monell's method of faradic dosage.

(66) How may general electrification be produced other than by faradic methods?

(67) State the general construction of the electric bath.

(68) Describe the monopolar bath.

(69) What disadvantage has the monopolar bath?

(70) Describe fully the dipolar bath.

(71) What apparatus are necessary in administering the electric bath, and why are they used?

(72) How may the amount of current the patient receives be determined?

(73) What percentage of the total current passing through the bath passes through the patient?

(74) On what do the physiological effects of induced coil-currents depend?

(75) Describe the action of slowly interrupted currents on non-striated muscles.

(76) Describe the action of rapidly interrupted currents on non-striated muscles.

(77) What is the length of the séance in pelvic applications when the rapid rate of the slow vibrator is used?

(78) State some advantages of the induction-coil current over the alternating current.

(79) How many effects can be produced by the intrapelvic applications of the coil-current?

(80) What is the object of central galvanization?

(81) What two centers are most important in central galvanization?

(82) What is the length of application to the cranial centers?

(83) What can you say of the sensations produced when the positive electrode is on the cranial center and the negative on the epigastrium?

(84) What is the object of passing the electrode along the anterior border of the sternoclidomastoid muscle?

(85) What is the length of application to the neck?

(86) What important nerves are affected in making an application on the ciliospinal center?

(87) What current-strength is used with the positive pole to the cranial center?

(88) What should be the temperature of the electric bath?

(89) What can you say of the use of acids and salts in the bath?

(90) Describe the method of administering the electric douche.

(91) How is the electric douche utilized in making applications to mucous surfaces and mucous cavities?

(92) What advantage has this application over those made to mucous surfaces with metallic electrodes?

(93) Describe the electric injection.

(94) What current is used in the electric injection?

(95) Describe the vaginal electrode of Doctor Cleaves.

(96) Name the different applications in which the electric douche is utilized.

(97) What can you say of the physiological effects produced by the electric bath?

(98) If sedative effects are required, what current should be used in the bath?

(99) What are the indications for the use of the galvanic current in the electric bath?

(100) What can you say of demedication by the electric bath?

(101) What are the different methods of administering general faradization?

(102) Describe the method of administering general faradization with metallic electrodes.

(103) What can you say of the use of the hand as an electrode in general faradization?

(104) What is the length of séance in central galvanization?

(105) Describe the difference between the effects produced by central galvanization and by local galvanization.

(106) What is the chief aim of treatment in central galvanization?

(107) What is the chief aim of treatment in general faradization?

(108) What is the general position of electrodes in general faradization?

(109) How is general faradization applied to children?

(110) What is the best method of producing muscular development?

(111) State the main points to be noticed in general faradization.

(112) Describe fully the method of using the hand as an electrode.

(113) Describe the application of faradization to the head.

(114) What can you say of faradization applied to the spine?

(115) What are the effects produced by the application of faradization to the ciliospinal center?

(116) How are the organs of the thoracic cavity treated?

(117) How are the lower limbs best treated?

(118) How is the current regulated when the hand is used as an electrode?

(119) (*a*) If the physiological development of muscles is desired, what is necessary to regulate the interruptions? (*b*) What should be the rate of interruption?

(120) Give a synopsis of the apportionment of the average application of general faradization.

(121) What can you say of the length of a séance, and of the time over which the treatment extends?

(122) What material is recommended for the negative electrode in general faradization?

(123) What attention does this electrode require?

(124) In general faradization, where is the current most annoying?

(125) What portion of the surface of the body is most sensitive to electric currents?

(126) What portion of the body is most tolerant to electric currents?

(127) In general faradization, on what part of the body should (*a*) the least time be devoted? (*b*) the most time be devoted?

(128) (*a*) What are the primary effects of general faradization? (*b*) What are the secondary effects of general faradization?

(129) No effects being produced by general faradization, when should treatment be discontinued?

(130) Describe the treatment of insomnia.

(131) What can you say of electrolytic and chemical actions in the use of alternating currents?

(132) What is the general action of general faradization?

(133) What can you say of the effect of electrical treatment on the nerve-structure of the cervical region?

(134) What are the indications for central galvanization?

(135) What are the effects produced by the alternate use of central galvanization and general faradization?

(136) On what do the finer therapeutic qualities of induction-coil currents depend?

(137) What is the special feature of the high-tension coil?

(138) Name the three factors that produce the special sensory, vasomotor, and motor effects of the modern improved faradic apparatus.

(139) Can the interruptions of coil-currents be regulated in a satisfactory manner with a rheostat in the primary circuit only?

(140) What does Rockwell claim in regard to central galvanization?

(141) Describe the method of applying galvanofaradization as introduced by de Watteville.

(142) What are the effects produced by galvanofaradization?

(143) (*a*) State the special indications for the use of galvanofaradization. (*b*) What can you say of the current-strength used in galvanofaradization?

(144) What aphorism should be borne in mind in determining the current-strength in making electrical applications to the body?

(145) What do Doctor Poore's experiments prove?

(146) By what means may the current passing through the bath be localized to the different parts of the patient in the bath?

(147) What is the usual duration of the bath treatment?

(148) When are the secondary coils under the maximum inductive influence of the primary coil?

(149) What disadvantages are there in using fixed electrodes on bath-tubs?

(150) Do coil-currents require any safeguard against electrolytic or cautery action?

The X-Rays.

THE X-RAYS.

(1) Give the different ways in which the charges on the prime conductors of the static machine may unite.

(2) Describe (*a*) a conductive discharge; (*b*) a disruptive discharge; (*c*) a convective discharge.

(3) Why does the disruptive discharge assume a zigzag instead of a straight line when the discharge-rods are separated several inches?

(4) What is the appearance of the discharge when the discharge-rods are separated about 12 inches?

(5) (*a*) On what does the brilliancy of the spark depend? (*b*) On what does the length of the spark depend?

(6) (*a*) On what does the E. M. F. of the static machine depend? (*b*) On what does the volume depend?

(7) What can you say of the color of the disruptive discharge?

(8) Describe the brush-discharge.

(9) How is the brush-discharge changed into a convective discharge?

(10) What phenomenon is noted at the negative pole during a convective discharge?

(11) What influence has a vacuum on the discharges of the static machine?

(12) (*a*) In how many ways can the vacuum of a tube be increased? (*b*) Describe them.

(13) (*a*) In how many ways can the vacuum of a tube be decreased? (*b*) Describe them.

(14) (*a*) What is a Geissler tube? (*b*) Describe it.

(15) What is the degree of vacuum of the Geissler tube?

(16) How may the various discharges of the static machine be studied?

(17) Describe the phenomena that occur when the discharge takes place in an electric egg during exhaustion.

(18) What electrical sources were used to produce X-rays in the first half of 1896?

(19) Why did the static machine fail to produce efficient X-rays during this period?

(20) What is the difference in price between a first-class coil and a therapeutic Holtz machine?

(21) Which do you consider the most desirable apparatus for X-ray work and medical examinations?

(22) Describe the method of testing a new static tube.

(23) When the vacuum of a tube is too low to be coaxed to efficiency, what is the color of the electric discharge in the tube?

(24) What can you say of the variability of the vacuum of Crookes tubes?

(25) How is the variability of the vacuum of a tube best reduced?

(26) (*a*) What are striæ? (*b*) Explain their action.

(27) What effect has a magnet on the discharges of a tube?

(28) Describe a Crookes tube.

(29) Of what metal are the electrodes of the Crookes tube made, and why?

(30) Of what metals are the inner extremities of the electrodes of the Crookes tube usually made?

(31) Describe the tube in Fig. 1.

(32) With a low vacuum, what occurs when the tube is connected to a source of high E. M. F.?

(33) What is the phenomenon of this Crookes tube with increased exhaustion, when the anode and cathode are connected to a source of high E. M. F.?

(34) What is the direction of the radiation of the cathode?

(35) Which anode is used to produce this effect?

(36) In a tube of high exhaustion, what becomes of the dark spot that appears at the cathode during the discharge?

(37) What is Crookes's explanation of the phenomenon produced by a tube of high exhaustion?

(38) (*a*) With the Maltese cross of Fig. 3 in the path of the cathode stream, what is the effect on the glass bulb? (*b*) What is the effect when the cross falls forward?

(39) Explain how Crookes proved the mechanical action of the effect of the molecules on the cathode.

(40) How is the change in the vacuum of the Crookes tube explained?

(41) What effect have the rays on the vacuum-tube?

(42) What is the proper vacuum of the static tube adapted to the modern Holtz machine?

(43) Do Crookes tubes increase or decrease in vacuum during work?

(44) What determines the life of a Crookes tube?

(45) (*a*) Describe the three methods of operating static tubes with the modern Holtz machine. (*b*) Which do you consider the best method?

(46) If you wished to handle the tube without stopping the machine, how would you shut off the current?

(47) What is the temperature of the apex of the cathode stream?

(48) Describe the Crookes tube by which the rays were carried outside the tube.

(49) What phenomenon occurs on sending an electric current through this tube?

(50) What effect has tin-foil on the rays?

(51) At what point of development did Crookes's investigations stop and Roentgen's begin?

(52) Where do X-rays start, and what relation do the cathode rays bear to X-rays?

(53) (*a*) What is the anticathode? (*b*) What is its function?

(54) What did Bartelli prove by placing a photographic plate in the path of the cathode stream?

(55) What was the effect produced by placing a photographic plate both inside and outside the Crookes tube, one in the path of the cathode rays and the other in the path of the X-rays?

(56) Give Roentgen's theory of the nature of X-rays.

(57) (*a*) Describe the ordinary focus-tube. (*b*) Why are they called focus-tubes?

(58) What is the shape of the cathode, and why?

(59) Describe the *standard X-ray tube.*

(60) How did Professor Roentgen discover X-rays?

(61) What chemical is now most used in the manufacture of the fluoroscope?

(62) Who introduced the tungstate-of-calcium fluoroscope?

(63) What advantage has the fluoroscopic screen over a negative?

(64) What is the best means of shortening the exposure?

(65) Is it possible to have too great a penetrative power when using X-rays?

(66) State the law of inverse squares.

(67) Does this law apply to X-rays?

(68) Is it necessary to have different tubes for examining different parts of the body?

(69) What tube should a physician purchase?

(70) Having a good tube, in how many ways may the efficiency of X-rays be reduced?

(71) Describe Crookes's method of reducing a vacuum.

(72) Is the vacuum of a tube more liable to go up than down?

(73) Describe fully the method of bringing a tube to its maximum efficiency.

(74) What indicates that a tube has reached the end of its useful existence?

(75) What should be done when a tube becomes too hot?

(76) Why should tubes be kept free from dust?

(77) What is the cause of *Dermatitis Roentgeni?*

(78) What are the two chief qualities of static currents?

(79) Does the static current heat a Crookes tube?

(80) While working with X-rays, what are the best means of preventing dermatitis, epilation, bleaching, etc.?

(81) (*a*) On what does the action of the cathode stream depend? (*b*) How is this proved?

(82) State some of the properties of the cathode rays.

(83) How can you explain that the effect on the dry plate or screen is not due to ordinary light radiated from the tube?

(84) On what does the E. M. F. of the secondary coil depend?

(85) Why is the secondary E. M. F. at "break" greater than at "make"?

(86) How are tubes rated?

(87) What does a "4-inch tube" mean?

(88) How may a 4-inch tube be used as a 2-inch tube?

(89) Why should several tubes be kept on hand?

(90) What is the difference between the 2-inch spark of a large coil and the 2-inch spark of a small coil?

(91) Why would a tube take a 5-inch spark from a small coil while it would not take a 2-inch spark from a large coil?

(92) How can you tell when a tube is worked beyond its capacity?

(93) What sized Leyden jars should be used in X-ray work?

(94) What sized induction-coil is necessary for X-ray work?

(95) How are induction-coils rated?

(96) What precautions are necessary in handling X-ray induction-coils?

(97) What current is necessary to operate the 10-inch coil?

(98) What is the function of condensers in the coil-apparatus?

(99) What do you understand by the theoretically correct vibrator?

(100) On what does the length of time necessary to charge a storage-battery depend?

(101) What is the source of current-supply for the Ruhmkorff coil?

(102) (*a*) Describe the interrupter of Fig. 10. (*b*) Explain its action when operating a coil.

(103) How is sparking between the platinum points prevented?

(104) Explain the effect of condensers on the "break-current" of the secondary coil.

(105) In what does the Tesla coil differ from the ordinary induction-coil?

(106) What is the nature of the current of the Tesla coil?

(107) Why is the Tesla coil insulated in oil?

(108) On what does the frequency of the Tesla coil depend?

(109) In what two ways may the Tesla coil be operated?

(110) Describe the connections when the Tesla coil is operated by the static machine.

(111) (*a*) Of what is the cathode stream composed? (*b*) How is this proved?

(112) Does a Geissler tube produce X-rays?

(113) If a tube produces X-rays, what is it called?

(114) What is the immediate source from which X-rays proceed?

(115) Which is the best type of X-ray tube for the static machine?

(116) Do X-rays differ in wave-length?

(117) What is the most common cause of decrease of vacuum in Crookes tubes?

(118) How is puncture of the tube produced?

(119) Why should the current be stopped before heating the tube to reduce vacuum?

(120) Can a punctured tube be repaired?

(121) (*a*) What is fluorescence? (*b*) What is phosphorescence?

(122) What fluorescent chemicals have been found to give the best service for examining X-rays?

(123) Which is the most extensively used, and why?

(124) How is the fluorescent screen made?

(125) (*a*) What is a fluoroscope? (*b*) Describe it.

(126) (*a*) Are all the X-rays converted into fluorescent rays? (*b*) What becomes of those that are not fluorescent? (*c*) How can that be determined?

(127) (*a*) What is a radiograph? (*b*) What two methods are there for making them?

(128) What are the main points to be remembered in making radiographs?

(129) How may a small object be held in place for a radiograph?

(130) What is seen on the screen when examining the body?

(131) How can the outlines of objects be made clear and distinct?

(132) Give a rule governing the distance of the plate from the object.

(133) (*a*) How can the reduction of the radiating surface be attained? (*b*) What objection is there to this method?

(134) What form of tube is used with the Tesla coil?

(135) What can you say of the definition of the image with a double-focus tube?

(136) What effect have X-rays on bodies that are electrified?

(137) If, at a short distance from the tube, the bones of the hand appear as transparent as the flesh, what would you do to make the outlines of the bone dark?

(138) State the objections to small tubes.

(139) Why were static machines not in use in early X-ray work?

(140) If a radiograph of the spine is to be taken, what is the position of the body in relation to the tube and plate?

(141) What is essential in order that the rays have sufficient power to penetrate the trunk of the human body?

(142) Why would not a low-vacuum tube do to observe the muscles of the trunk?

(143) What is gained by using several plates in taking a radiograph of the body?

(144) What can you say in regard to the length of exposure?

(145) In taking a radiograph, what is the relation of the tube, body, plate, and screen?

(146) Can X-rays be photographed by an ordinary camera?

(147) After X-rays are fluoresced, what do they become?

(148) Describe the process of making an enlarged or reduced copy of the image that appears on the fluorescent screen.

(149) Why is the front of the camera covered with lead?

(150) Will X-rays penetrate lead?

(151) What is the effect of compressed air on electrical discharges?

(152) Do cathode rays disperse again after they are brought to a focus?

(153) Have X-rays any calorific effect?

(154) What are the essentials of good X-ray work?

INDEX.

INDEX.

Date Due

OUL APR 29 '48		